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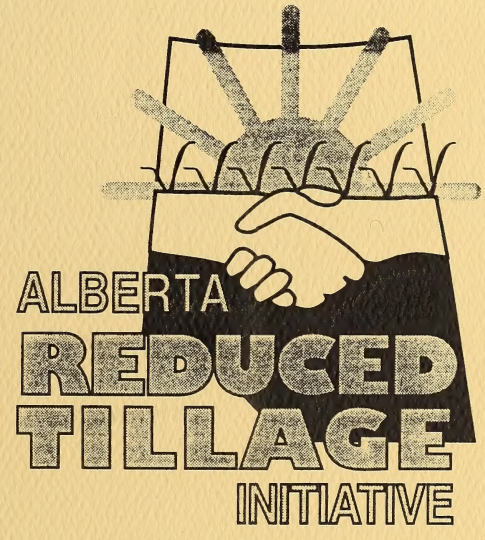
Proceedings
of

DIRECT SEEDING
"Back to the Future II"



January 16, 1997
Dunvegan Motor Inn, Fairview, Alberta

WORKING FOR A BETTER AGRICULTURAL INDUSTRY IN ALL PARTS OF ALBERTA

PFRA

ALBERTA CONSERVATION TILLAGE SOCIETY

Alberta
AGRICULTURE, FOOD AND RURAL DEVELOPMENT

Acknowledgements

Thanks to all the participants, speakers, helpers and the Dunvegan Motor Inn for their involvement in the DIRECT SEEDING WORKSHOP: BACK TO THE FUTURE II, held on January 16, 1997 in Fairview. One hundred twenty-five people attended from as far as La Crete, Valleyview and Wembley.

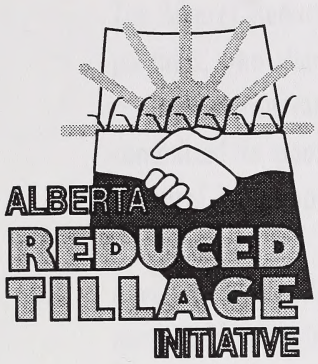
Special thanks to the organizing committee, including Randy Perkins, Randy Graw and Blair English, for their assistance in locating sponsors, speakers, and setting up and chairing sessions.

Thanks to the sponsors, including Farm Credit Corporation, Canadian Agra Foods (Northern Lights Canola), Alberta Reduced Tillage Initiative, Municipal District of Clear Hills, Monsanto, PFRA, CAESA, and Alberta Agriculture, Food and Rural Development.

Thanks to those who set up displays. We appreciate the door prizes from Ducks Unlimited, Zeneca, Dow Elanco, ARTI and Monsanto. Thanks to the Alberta Wheat Pool for printing the brochures. Thanks to the Peace Region Association of Alberta Agriculture Fieldmen treasurer John Knoot who processed the income and expenses.

A special thanks to Linda Brazel for collecting, "cleaning up" and producing these proceedings.

John Zylstra
Conservation Coordinator
Conservation and Development Branch
Alberta Agriculture, Food and Rural Development



Meetings, Courses, Demonstrations and Tours will provide answers to your crop production needs, including:

- Equipment Requirements/Options
- Residue Management
- Weeds Management
- Fertility and Placement
- Systems Planning
- Economics of Direct Seeding and Reduced Tillage Farming Systems.

Watch for more details on Alberta Reduced Tillage Initiative events in your area.

A Partnership for Conservation, Production and Profit.

If you are interested in hosting an event, or have an idea for one please contact the Alberta Reduced Tillage Initiative Provincial Coordinator or your Alberta Agriculture, Food and Rural Development Regional Conservation Coordinator.

The Alberta Reduced Tillage Initiative is a dedicated group of agricultural partners, who share a common philosophy about reduced tillage and the resulting conservation, production and economic benefits. They have committed to pool resources for three years to provide leading-edge, practical information to Alberta producers.

A variety of events are being developed and will be designed to meet local needs and solve local problems. These are being developed and presented in partnership with local and regional partners, including: Regional Conservation Coordinators, Crop Specialists, Agricultural Fieldmen, Applied Research Associations, PFRA, Producer Groups, Industry Specialists and Producers.

The Partners believe that conserving soil and water resources through reduced tillage practices will improve the economic viability of Alberta farmers and the long-term sustainability of the agriculture industry. The objective is to help Alberta farmers put reduced tillage farming practices and technology to work.

The Partners are pleased to present this Initiative and invite you to participate.

Foundation Partners:

Monsanto Canada Inc.

Alberta Conservation Tillage Society

Conservation 2000

Alberta Prairie Care

Olds College

Sherritt Fertilizers

Alberta Agriculture, Food and Rural Development

CONTRIBUTING PARTNERS:

United Farmers of Alberta

DowElanco Canada Inc.

Western Cooperative Fertilizers Inc.

ACKNOWLEDGEMENTS:

Association of Alberta Agricultural Fieldmen

Canada-Alberta Environmentally Sustainable Agriculture Agreement (CAESA)

Prairie Farm Rehabilitation Administration (PFRA)

ALBERTA REDUCED TILLAGE INITIATIVE

SCHEDULE

Thursday, January 16

9 am	Registration
9:15	**Fertilizer placement, urease inhibitors** Doon Pauly, Research Agronomist with Agrium
10:00	**Farmer experiences in direct seeding** Claus Toerper, direct seeder of 2,500 acres near Wembley, using anhydrous with airdrill
10:30	Coffee break
11:00	**Integrated weed control in direct seeding** Dr. John O'Donovan, Research Scientist in Weed Management at the Alberta Environmental Center at Vegreville for 18 years
11:40	**Farmer experience with peas in sod** Danny Lane/Dale Seward
12:00 pm	Lunch (on your own - buffet available)

Select-a-Sessions

1:00	**Peas, innoculants and fertility** Dr. George Clayton, Researcher with Ag Canada at Beaverlodge and Ft. Vermilion
	Oats into fescue sod Garry Ropchan, Central Peace Conservation Society Manager, and direct seeder
1:30	**Variety trials and fertility** Richard Lussier, Soils Specialist
	Direct seeding annual crops into sod Jeff Prochnau, Research Agronomist
2:00	**Value of crop rotations** John Zylstra, Conservation Coordinator
	Dugout water quality Reynold Woelcke, Water Development Technician
2:30	Coffee break and displays
3:00	**Global positioning systems and precision farming** Murray Green, Alberta Agriculture Engineer
3:45	**Roundup ready canola** Grant Mitchell, Monsanto

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Fertilizer Placement Issues for Direct Seeding

Doon Pauly

Research Agronomist
Agrium Inc., Edmonton

Introduction

Technological advancements in seeding equipment have made one pass seeding with fertilization a common management practice in western Canada. Dry granular fertilizers, anhydrous ammonia, and fertilizer solutions applied in the seeding operation, in a variety of soil and climatic conditions, can all produce excellent stands and yield. In spite of the advancements in farm equipment, fertilizer placement with direct seeding continues to be a concern possibly because equipment upgrades are not always economically feasible, new seeding systems with a lot of iron in the ground require substantial horsepower for pulling, or because there is a continual push towards doing more work in less time and fertilizer applications unnecessarily delay seeding operations. Rather than addressing numerous fertilizer placement issues, this paper will focus on broadcast urea (46-0-0) fertilization and seed-placed urea fertilization for direct seeding situations.

Broadcast Urea Fertilization

In many parts of the world broadcasting granular fertilizers on the soil surface, with or without tillage to incorporate the fertilizer, is by far the most common form of fertilization. In western Canada, banding or seed-placing fertilizer is more common than broadcasting primarily because of increased fertilizer use efficiencies with these applications.

Although there are inefficiencies associated with broadcast fertilization, there are also some advantages. Broadcast fertilization is fast and easy, which makes it an attractive management practice for some producers, especially in years when adverse weather conditions shorten the seeding season. Application equipment can carry large volumes of fertilizer and can cover substantial areas without refilling. A subsequent seeding operation can then proceed relatively quickly because large volumes of fertilizer do not have to be handled at seeding and available space in seeding equipment can be dedicated to seed, allowing more acres to be seeded without stopping to refill.

One of the major disadvantages of surface applied urea (46-0-0) is that nitrogen in broadcast fertilizer can be lost back to the atmosphere in a process known as volatilization or gassing off. When urea is applied to soil it dissolves in soil water and is rapidly hydrolyzed in a reaction initially catalyzed by the enzyme urease. The reaction is as follows:

$$\underset{\text{(urea)}}{CO(NH_2)_2 + 2H_2O} \leftrightarrow \underset{\text{(ammonium carbamate)}}{(NH_4)_2CO_3}$$

Ammonium carbamate is unstable and rapidly decomposes to form carbon dioxide, water, and ammonia/ammonium. Ammonia and ammonium will establish an equilibrium dependent on soil pH and concentration or partial pressure of the species present.

$$(NH_4)_2CO_3 + H_2O \rightarrow CO_2 + NH_4^+ + OH^-$$
$$\underset{\text{ammonium}}{NH_4^+} \leftrightarrow \underset{\text{ammonia}}{NH_{3(g)}}$$

Higher soil pH's (>7.8) drive the reaction to the right favoring ammonia (NH_3) production rather than ammonium (NH_4^+). Similarly, as the concentration of ammonium increases, the reaction again is driven right producing ammonia. Fertilizers such as ammonium nitrate (34.5-0-0) or urea ammonium nitrate (UAN: 28-0-0 solution) have a portion of their nitrogen in the nitrate form and are not as prone to suffer volatile N losses. Since these products contain a substantial amount of nitrate, ammonium concentrations are lower and consequently ammonia production is lower.

When urea is applied to the soil surface and not incorporated (either with tillage or with adequate rainfall), nitrogen in the free ammonia form can readily be lost to the atmosphere. When urea is incorporated into soil, ammonium ions (NH_4^+) can be held by clay and organic matter and nitrogen will not be lost as ammonia.

The hydrolysis of urea requires very little soil moisture and the rate of hydrolysis increases as soil temperature increases. The urease enzyme is released from living or decaying microorganisms or plants and is both abundant and universally occurring in soils. Consequently, urea hydrolysis proceeds rapidly on soils that are warm and wet enough to support plant life.

N-butyl thiophosphoric triamide (NBPT; when applied to urea the treated product will be abbreviated UNBPT) has been identified as an effective urease inhibitor by reducing ammonia volatilization from surface applied urea. NBPT or other effective urease inhibitors have the potential to minimize the limitations of surface applied urea fertilizer.

Ammonia volatilization experiments were performed at Agrium's New Products lab on a number of soils with varying chemical and physical properties. Results using soils taken from research sites at Sedgewick, Fort Saskatchewan, and Coaldale are given as examples (Figures 1-3). In general, NBPT was found to delay urea hydrolysis. The Sedgewick soil was very coarse textured (>80% sand, pH 6.0) and generally had the quickest rate of ammonia evolution as well as the highest cumulative gaseous N loss, possibly indicating that the coarse soil did not have the adsorptive properties necessary to retain ammonia/ammonium. Even with these soil conditions, ammonia evolution from treatments with NBPT was considerably lower than from untreated urea. On the other two soils, NBPT either delayed urea hydrolysis for 8-10 days (Fort Saskatchewan, Figure 2; 55% sand, pH 6.4) or from 15-20 days (Coaldale, Figure 3; clay loam, pH 7.8).

Figure 1. Soil urease inhibition by NBPT: Sedgewick

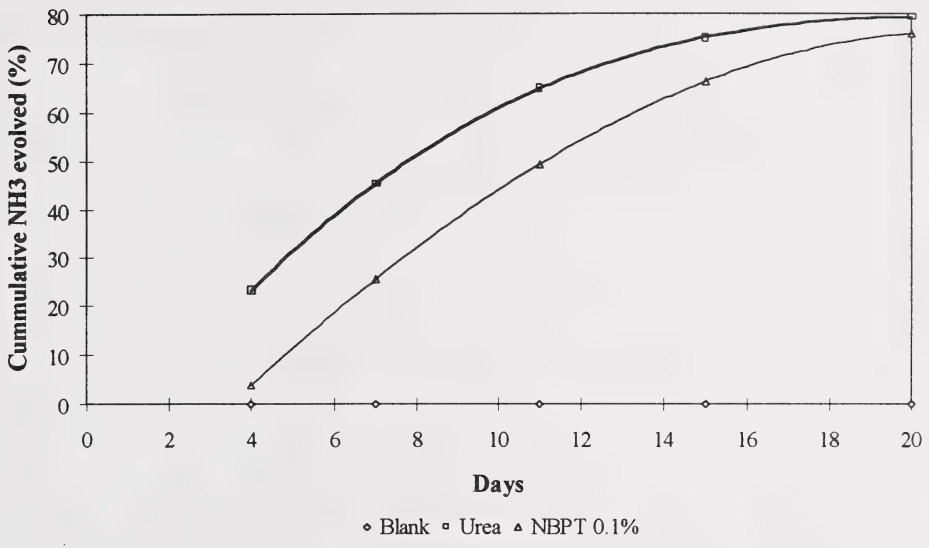


Figure 2. Soil urease inhibition by NBPT: Fort Saskatchewan

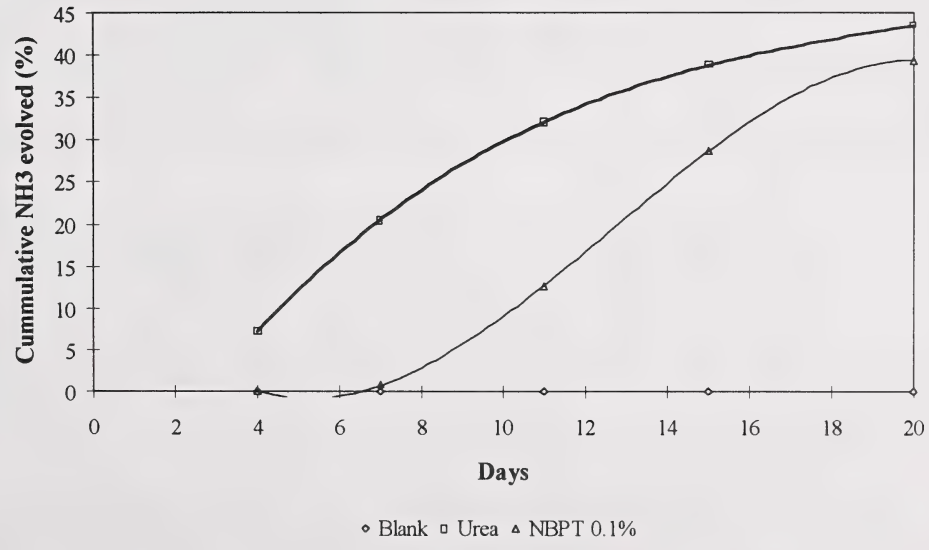
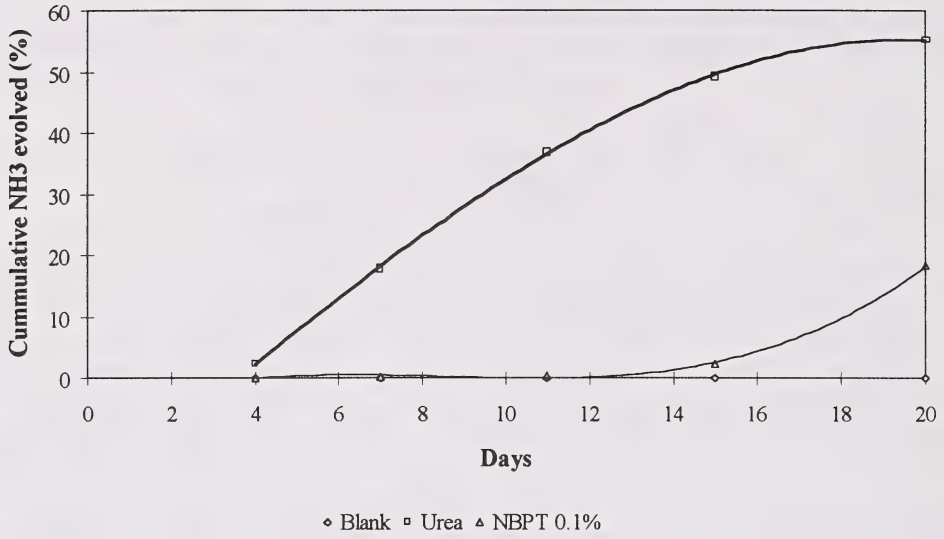


Figure 3. Soil urease inhibition by NBPT: Coaldale



Dr. Grant with Agriculture Canada at Brandon has worked with urease inhibitors and has also performed ammonia volatilization experiments. In micro-plot field experiments Grant *et al* applied nitrogen fertilizers to the soil surface (177 mg N which equated to about 90 lb N ac^{-1}) and trapped ammonia evolution over 7 days. The experiment was performed in the spring (May) on cool soils and in the summer (August) when temperatures were considerably higher. Under both temperature regimes NBPT reduced volatile ammonia losses from both granular urea and UAN (28-0-0) solutions (Table 1). These results confirm that NBPT effectively delays urea hydrolysis.

Table 1. Volatile losses of ammonia (mg N) from nitrogen fertilizer applications with and without nBPT (from Grant *et al*, 1996)*

Treatment	Day 1		Day 2		Day 4		Day 7		Total	
	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer	Spring	Summer
Control	0.000a[1]	0.133a	0.000a	0.125a	0.000a	0.150a	0.000a	0.208a	0.000a	0.617a
Urea	0.183bc	1.208bc	6.592c	34.275d	26.175c	43.792c	7.733e	8.783b	40.683d	88.058d
UNBPT	0.000a	0.200ab	0.050a	0.300ab	0.233a	3.050ab	2.042c	8.767b	2.325b	12.317b
UAN	0.283c	1.117bc	0.525b	2.267c	1.275b	15.258b	5.042de	31.167c	7.125c	49.808cd
UAN+NBPT	0.092ab	0.650ab	0.067a	0.983b	0.275a	5.008b	0.692b	9.900bc	1.125b	16.542b

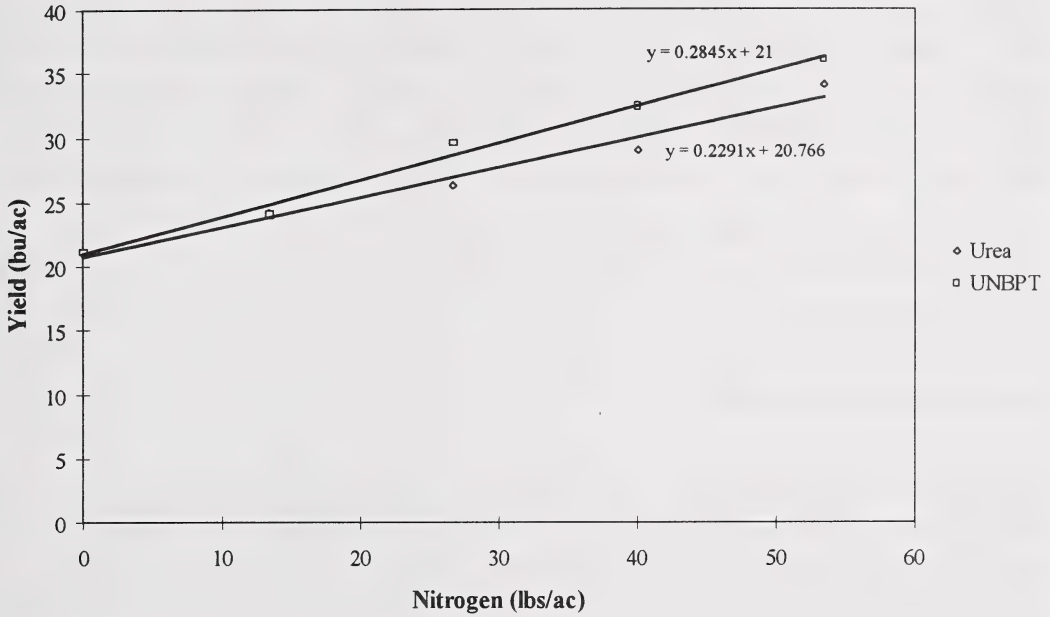
*Paper submitted to the Canadian Journal of Soil Science for publication

[1] Numbers within each column followed by the same letter(s) are not different at the 5% probability level using Student Newman Keuls test for means separation on log transformed data

Agrium has performed broadcast nitrogen experiments with spring seeded crops at a total of 7 sites over 2 years. At 6 of these site-years there was no yield advantage with NBPT compared to untreated urea either because volatilization did not occur or soil nitrogen met the crop's requirements so that volatile losses were not detectable. Only at 1 site in 1 year was there a yield

advantage with NBPT (Figure 4). Across the N application range at this site UNBPT produced higher yield than urea probably due to higher N use efficiency.

Figure 4. Wheat yield with surface applied urea or NBPT treated urea at Kirriemuir



NBPT has the potential to improve the efficiency of broadcast urea but this benefit will only be measurable when native soil nitrogen levels are low, environmental conditions following seeding encourage volatilization, growing season conditions promote good growth so yield is limited by nitrogen losses, and rainfall eventually washes UNBPT into the soil. In many cases NBPT may not be necessary because producers can asses the volatilization potential of their land and manage accordingly (Table 2).

Table 2. Conditions following fertilization that affect nitrogen volatilization

High Volatilization Potential	Low Volatilization Potential
CLIMATE	
< one half inch of rainfall	> one half inch of rainfall
High soil temperature	Low soil temperature
Moist soil surface	Dry soil surface
High wind speed	Low wind speed
SOIL	
Coarse soil texture	Fine textured soil
Low organic matter content	High organic matter content
High lime content	Low lime content

When urea is broadcast onto cold, fine textured soils when there is a good chance for sufficient rainfall to wash the fertilizer into the soil, then volatile losses would be small. However, when urea is applied to warm soil and not washed into the soil by rainfall, then the nitrogen loss potential is high, especially on coarse textured and/or higher pH soils.

Broadcast fertilizer applications are fast and easy, often allowing seeding operations to proceed with fewer delays. Spring applications of broadcast urea without incorporation can suffer volatilization losses, but these losses can be minimized by applying the fertilizer to cool soils when there is good potential for rainfall. Spring broadcast applications of nitrogen fertilizer with nitrate nitrogen are not as prone to volatile N losses as urea nitrogen and their use is another management strategy for producers interested in broadcasting their nitrogen. It must be remembered that volatilization losses are not the only negative aspect of broadcast fertilization but these other factors (such as nitrogen immobilization, stranding of nutrients above the crop's rooting zone, or fertilizing so that weeds and the crop have equal access to the fertilizer) will not be considered in this paper.

Seed-Placed Fertilization

For many years seed-placed fertilization was not an issue since desired fertilizer application rates clearly exceeded capabilities of conventional seeding equipment. Furthermore, seed-placement of fertilizer wasn't needed since fertilizer application could easily be coupled to a tillage operation. Seed-placement of all necessary fertilizer has become common as producers have switched to direct seeding systems. It is estimated that about 30% of all urea used in western Canada is seed-placed.

Although seed-placed fertilization is common, there are numerous risks associated with the practice. Seed-placed fertilizer can delay germination, increasing the days necessary for crop maturation. Concentrated fertilizer near seeds can be toxic either to the seeds or seedlings, reducing plant populations. This stand reduction can lower yield but also can cause maturity delays as plants tiller to fill vacant space and ripen slowly. Stand reduction also leaves considerable open ground so that weeds flourish and consume valuable nutrients and water. In many cases fertilizer placed in the seed-row with the intention of promoting growth and increasing yield, causes stand reduction and yield lower than would have been achieved without any fertilizer.

Seed-placed fertilizer damages seeds and seedlings by two different mechanisms depending on the type of fertilizer used; seed-placed fertilizer damage is either due to a salt effect or ammonia toxicity. All soluble fertilizers exert a salt-like effect on soil moisture, tying up that water so that it is not available for seed germination or for developing seedlings. Ammonium nitrate (34.5-0-0) is an example of a fertilizer product that primarily causes salt damage. For cereal crops, ammonium nitrate is relatively safe but for canola and other small seeded crops the salt damage of this product can be severe. Urea (46-0-0) has salt-like properties but also can lead to ammonia toxicity when seed-placed. In the previous discussion about urea hydrolysis, the reactions demonstrated that urea application ultimately produces ammonium/ammonia. High

concentrations of ammonia near seeds or seedlings are toxic whether the crop is a cereal or an oilseed.

There are numerous factors that affect the severity of seed-placed fertilizer and the maximum safe application rates. Soil moisture at seeding and in the first several days following germination is probably the most dominate factor. Moisture reduces or eliminates the toxic effects of fertilizer by diluting the salts or ammonia. Whether the potential damage is from salt or ammonia, abundant moisture produces a favorable environment for growth. Alberta and Saskatchewan recommendations for maximum safe seed-placing rates assume excellent moisture conditions and strongly caution that rates need to decrease with less favorable moisture. With little available moisture, salts and ammonia remain concentrated and can be lethal.

The mechanized seeding operation can also affect the concentration of fertilizer near the seed and the beneficial or detrimental effect of seed-placed fertilizer. As seedbed utilization (SBU: width of seed/fertilizer spread divided by row spacing) increases, seed and fertilizer are spread throughout more soil, the toxic effects are diluted, and damage is minimized. Maximum seed-placed fertilizer damage occurs when seed and fertilizer are placed very close together (double disc or knife opener) and minimal damage occurs when seed and fertilizer spread is wide as it would be behind a shovel opener.

The soil properties that affect ammonia volatilization (texture, organic matter content, and pH) also can affect the ammonia toxicity of seed-placed fertilizer. Clay and organic matter can both hold ammonium ions and essentially reduce ammonia concentrations. As was discussed with volatilization, ammonia tends to dominate the ammonium/ammonia equilibrium as soil pH increases, so soils with high pH would tend to be more prone to ammonia toxicity damage.

Large seeded crops (cereals) are less likely to suffer damage from seed-placed fertilizer than are small seeded crops (canola and flax). Generally, the sensitivity of various crops to seed-placed fertilizer (from least sensitive to most sensitive) would be: oats, barley, wheat, canola, and flax. Both Alberta and Saskatchewan guidelines for seed-placed fertilization have relatively higher allowable limits for cereals than they do for oilseeds.

Agrium has worked with the urease inhibitor NBPT for several years. In our lab work we found that the inhibitor effectively delayed ammonia losses from surface applied urea indicating that it was delaying urea hydrolysis. Since NBPT effectively delayed urea hydrolysis we speculated that NBPT treated urea (UNBPT) should be much safer than urea for seed-placing. Theoretically, seed and UNBPT would not need to be physically separated if rainfall diluted urea concentrations near seeds prior to hydrolysis. Although rainfall would also minimize the toxic effects of conventional urea, the rainfall would have to be within a few days of seeding or else toxic conditions would develop. Delayed urea hydrolysis would minimize toxic conditions allowing for a prolonged rainfree period following seeding.

To test our hypothesis, seed-placed fertilizer experiments were performed with barley, wheat, and canola at a number of locations in Alberta and Saskatchewan. Generally each location had both a canola and a cereal experiment. The experiments were arranged in a randomized complete block

design with banded urea, seed-placed urea, and seed-placed UNBPT all applied with 5 N application rates (0, 22, 45, 67, and 89 lbs N ac^{-1}) replicated 3 times. In addition to the seed-placed nitrogen, canola and cereal experiments had 22 lbs P_2O_5 ac^{-1} applied in the seed-row, and the cereals had a further 13 lbs K_2O ac^{-1} seed-placed. All plots were seeded with an air drill using Bourgault 3" spoons on 8" centers with on-row packing.

Treatment effects were visible (reduced stand) at most locations throughout the growing season (at three sites in central Alberta there were no visible differences because of abundant rainfall [~2"] in the first two weeks following seeding). A site at Davidson SK had the most severe treatment effects with canola emergence severely impaired even by phosphate fertilizer alone. Although visible treatment effects were apparent during the growing season, these effects were not always present at harvest (Table 3). Early in the 1995 season it was estimated that about 75% of the sites would have been Effective at harvest so the number of sites where there were no differences between product/placements was surprising. This was especially true for canola where few sites were expected to be classified Not Needed. Apparently the canola stand was not reduced below the point where the remaining plants could compensate in yield.

Table 3. 1995 Seed-placed experiments where NBPT was effective, ineffective, or not necessary for reducing the toxic effects of seed-placed fertilization[†].

Crop	Effective[1]	Not Needed[2]	Ineffective[3]	Total
Barley	6	2	0	8
Wheat	5	3	0	8
Canola	4	8	2	14
Total	15	13	2	30

[†] Product effectiveness is based on yield comparisons between the different product/placements averaged across the N application range.

[1] Effective: Average yield from UNBPT>yield from seed-placed urea; UNBPT≥banded urea

[2] Not Needed: no yield difference between banded urea, seed-placed urea, and seed-placed UNBPT.

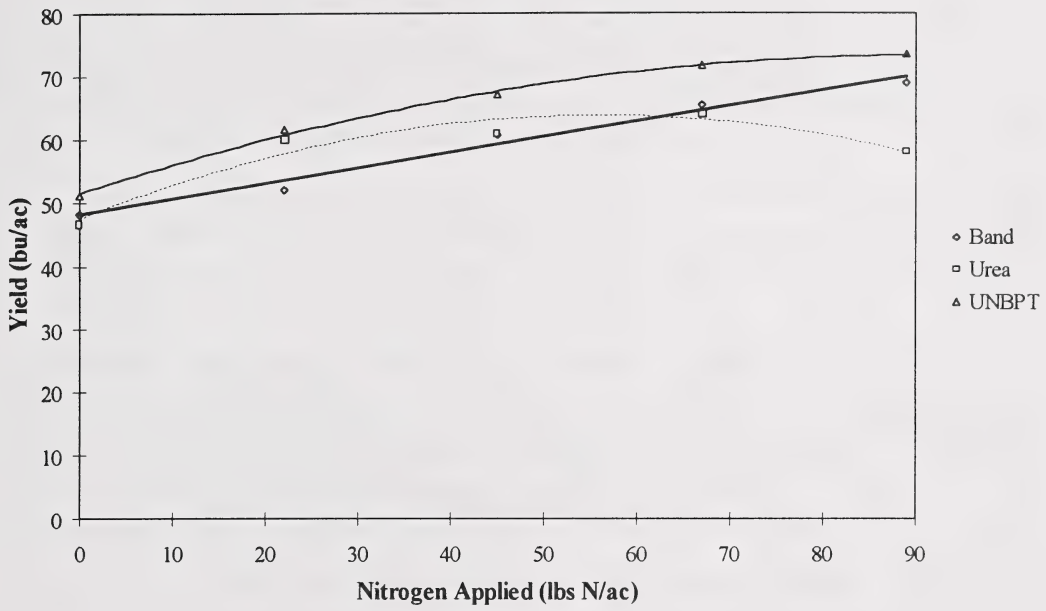
[3] Ineffective: yield from banded urea>seed-placed urea=seed-placed UNBPT

Data from the sites where NBPT was effective were combined to aid in determining the overall effect of NBPT. At these sites, the barley yield response to banded N was linear across the N application rate, and the response to seed-placed N (urea or NBPT) followed quadratic curves (Figure 5). Averaged across all N rates, barley yield with seed-placed UNBPT was higher than either banded urea or seed-placed urea. Although the average effect of banded urea and seed-placed urea are the same, at 22 lb N ac^{-1} yield was higher from seed-placed urea than banded urea while at 89 lb N ac^{-1} yield was higher with banded than seed-placed urea. The highest barley yield at every N application rate was achieved with seed-placed UNBPT. Seed-placed urea and UNBPT had similar yield at 0 and 22 lb N ac^{-1}, but apparent toxicity effects caused the yield from the 2 N sources to diverge at N rates above 22 lb N ac^{-1}.

The maximum safe seed-placed urea application rate with barley (using banding as the standard) appears to be about 67 lb N ac^{-1}. The maximum safe N application rate for barley with UNBPT is higher than the application rates used in this experiment. It must be remembered that these maximum rates were established with seeding equipment that had relatively low soil disturbance

yet still had considerable seed and fertilizer scatter (SBU). These rates therefore are not universal since lower or higher SBU would alter maximum allowable rates.

Figure 5. Seed-placed nitrogen with barley: Combined effective sites



The wheat experiments produced results similar to the barley experiments. The wheat yield response to banded nitrogen was primarily linear across the N application rates (Figure 6). The yield response from seed-placed urea or UNBPT followed quadratic curves. With wheat there was no overall yield difference between banded urea and seed-placed UNBPT. The maximum safe N application rate with seed-placed UNBPT (relative to the banding standard) was therefore 89 lb N ac^{-1}. The overall yield from seed-placed urea was lower than the yield from seed-placed UNBPT or banded urea. The maximum safe seed-placed nitrogen rate (relative to the banding standard) using urea appears to be between 45 and 67 lb N ac^{-1}.

Canola yield increased linearly with increased banded nitrogen or seed-placed UNBPT (Figure 7). However, the yield with increased seed-placed urea followed a quadratic curve. The overall yield response with seed-placed urea was lower than either seed-placed UNBPT or banded urea which were similar. The maximum safe rate of seed-placed UNBPT was higher than the N application range used in this experiment (at least 89 lb ac^{-1}). The maximum safe rate of seed-placed urea appears to be about 67 lb ac^{-1}. It must again be noted that the seeding equipment produced considerable seed and fertilizer scatter (utilized about 25% of the seed-bed) so safe seed-placed urea and UNBPT rates are not universally applicable to all seeding operations.

Figure 6. Seed-placed nitrogen with wheat: Combined effective sites

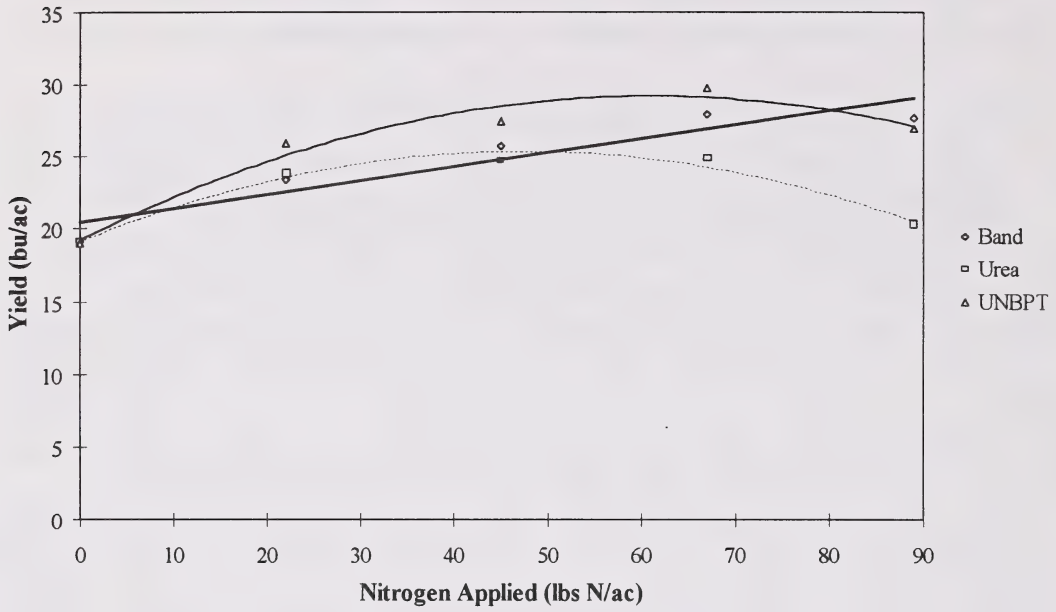
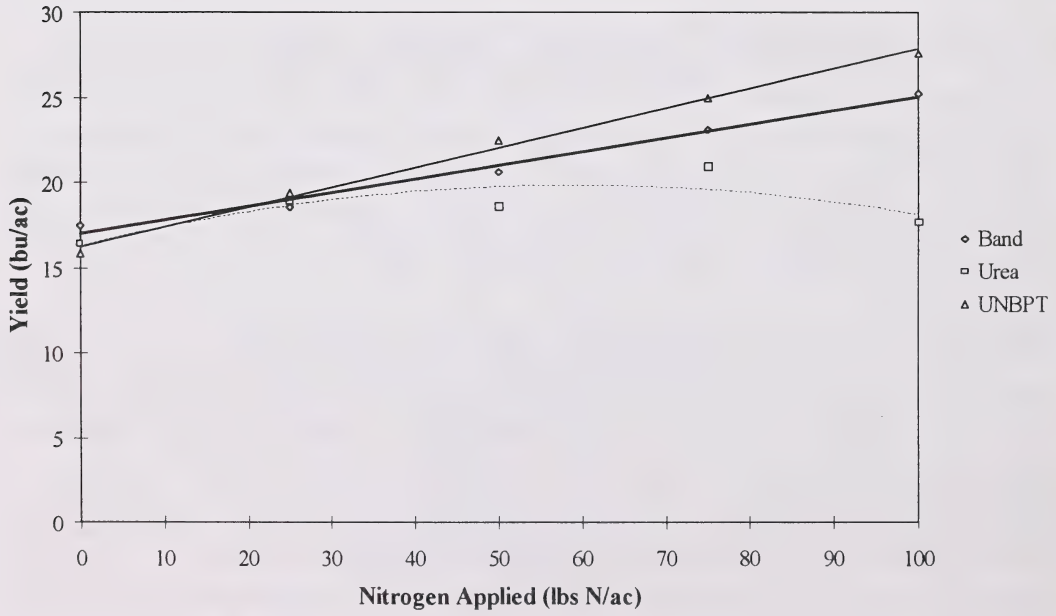


Figure 7. Seed-placed nitrogen with canola: Combined effective sites



Our field research with NBPT for seed-placed applications revealed that the product can reduce the toxic effects of seed-placed urea and can increase the maximum safe rate of seed-place urea. Although these experiments were performed at a number of sites with a variety of soil and climatic conditions the overall conclusions must be considered with some caution. Our seeding equipment was considered to represent a tradeoff between allowing some seed and fertilizer scatter yet minimizing soil disturbance. If we had been using equipment with a lower SBU, our maximum safe rates would probably be lower. The conclusions should also be viewed with caution because we had 2 sites where all seed-placed nitrogen treatments had lower yield than banded nitrogen treatments. It was very clear that even with some reduced potential for toxicity problems, seed-placing fertilizer is risky and can lead to crop failure.

Agrium's research work with NBPT revealed that the urease inhibitor NBPT can minimize the volatilization problems associated with surface applied urea and the ammonia toxicity problems from seed-placed urea. Even though the product is effective, there is considerable uncertainty if the product will ever reach the Canadian market due to high costs.

Seed-placed fertilization can be an effective crop production practice, but it also can have disastrous results. In recent years Alberta and Saskatchewan have both published updated guidelines for maximum safe seed-placed fertilizer rates. These guidelines are excellent tools but they both caution producers about the detrimental effects of seed-placed fertilizer. Producers wanting to seed-place fertilizer are encouraged to base application decisions on current recommendations and their own understanding of their land and seeding equipment.

Farmer Experiences in Direct Seeding

Claus Toerper

Producer, Wembley

My name is Claus Toerper. Many of you knew my father, Jasper Toerper. I farmed with my father until last year when he lost his battle to cancer. So I ended up doing a whole lot of learning in this past year. It's amazing how much one takes for granted when you work in a close partnership with someone. One of the things that my Dad tried to impress upon me was "learn from other people's mistakes, you won't live long enough to make them all yourself". Well last year I was well on my way to proving him wrong. You'd be amazed at how many mistakes you can pack into a year like last year. But mistakes aren't all bad unless you don't learn from them. And I did do a lot of learning.

I guess I'll start by giving you a little history about my farming background. I'm not going to pretend that I have all the answers or that someone out there may be able to do things a lot better than me. I'm still pretty young, but I do have enough experience and exposure to the farming world to be able to relate my experiences to you. If you're at all like me you come to functions like this one to hear how others do things and if you walk away with one idea you can use it was probably worth the trip.

I started farming with my Dad about 10 years ago. At that time his farming operation would probably have been classed as conventional till farm. He didn't believe in excessive tillage, but there were still fall cultivations, chemical incorporations, etc. . .

We started to look for ways to reduce work loads and move to a minimum till system. We dropped the fall cultivation and basically made two passes in the spring, with the occasional exception. The basic plan of attack was that I would run ahead with a 31 foot HD cultivator equipped with a hydraulic rod weeder and mounted harrows which left a fairly nice even and firm seed bed. The cultivator was also equipped with a small frame mounted airseeder and a cold flow kit. All the fertilizer was applied in one application.

Dad would then come along with 28 feet of International 7200 hoe drills which had very good trash clearance. I guess what we had was basically a poor man's Seedovator. The problem that we would run into is that we still found a need to do a preseeding burn off to control quackgrass, which could get a little out of control due to the lack of tillage. This was before the advent of preharvest Roundup.

We were keeping our eyes on the development of zero-till equipment and felt fairly comfortable making a move and buying a Harmon 3680 airdrill two years ago. Now most of the advice you hear is don't go into zero-till all at once. Do it over time, get your feet wet and learn as you go. But we didn't figure we could justify two lines of equipment and pretty much traded off all our old equipment on the new drill.

What we bought was a low disturbance hoe drill capable of fitting into pretty much any type of farming operation from conventional to zero-till. We went to 12 inch row spacing for a variety of reasons: less initial cost, less maintenance, lower draft and less soil disturbance. We equipped the drill with a pair of Haukaas disc markers and a Kee ultrasonic depth control.

The first year we used the drill we put all of our N down as dry product and though it was nice to handle that way it meant for a lot of fills and quite a bit of trucking, not to mention quite an increase in cost per acre. I was looking for a way to get back to using NH_3 but I was not sure how I could do it and keep my options open for seed/fertilizer separation when I was seeding my peas. I didn't want to be rearranging hoses and tubes between crops and I was looking for a way to triple shoot my products. I heard that Harmon had come out with a triple shoot shank but I didn't want to re-rig a new drill and cost was certainly an issue. So with a little head scratching I came up with what I have now and am very pleased with it.

I guess we all get a little tired at the pace of change these days and would like to leave things alone and not always have to tinker and try to improve the equipment we've got. But sometimes a little tinkering can mean a lot of time or money saved down the road. And that's what happened by being able to apply NH_3 at the time of seeding. To apply the ammonia I went to a radar control Dickey-John system which automatically compensated for ground speed irregularities and/or tank pressure changes due to temperature. I can also change rates on the go from the tractor and have a continuous readout of how much product I'm putting on. I always hated having to guess where to set the meter. This way I have a lot more control. Though all this stuff is nice it's not without its problems. A short or broken wire can cause you all sorts of grief. I recommend that when you install things like this you take your time and secure all wires neatly and out of the way.

Although using NH_3 worked very well for me last year there are several things I would recommend to you.

1. Be careful how you route your ammonia lines. Make sure that you take the time to check that none of the lines can get pinched, kinked or stretched. Make sure that your openers and shanks won't freeze off with product if combining with dry fertilizer. Frozen dirt build up is much more serious on the drill than if you are just banding. Precise seed placement can be lost and seedling damage will be much more likely. You can also have an unnecessary amount of soil movement.

2. Use an ammonia test kit which is available from AWP and make sure that you have adequate separation (1-2 inches). All the benefits from using ammonia are worthless if you get seedling damage from inadequate separation. The kit is easy to use and if your Pool rep is as easy to get along with as mine he'll come do the test for you and I don't even buy my fertilizer from him. My ammonia was separated approximately one inch below and between the seed rows in a band approximately the size of a quarter. I contribute much of that to the ample moisture we had last year. And even though I know it worked well last year I'll check it again this year just so I'll be able to sleep a little better at night. One of the nice things about the Harmon drill is that you can adjust the seed/fertilizer separation and in drier conditions it may be advised to increase the separation.

3. Safety is something that may get overlooked, but make sure you have proper safety chains between all units. On my outfit I can't see the ammonia tank when I'm going straight and have no idea what is going on other than what my monitor tells me. The whole unit is over 90 feet in length and you wouldn't want something to let go going down the road. I have to travel the highway quite a bit and had a reminder last year how quickly a disaster could happen. We were very lucky that we were in the field and that we were seeding peas and didn't have the ammonia tank behind. But the draw pin that connects the aircart to the drill had a manufacturing flaw. The top fell off the pin and the pin slipped through the hitch—no safety chain there. The cart unhooked, pulled apart all hoses and wires and pulled the ammonia hose off the controller along with the line strainer and snapped back like a slingshot and dented the air seeder tank. I didn't have a breakaway for the ammonia line there because my dealer thought that two breakaway couplers in the system may create too much back pressure to work properly. The way things were I was mobile again within an hour, but had that happened on the highway with the ammonia tank I hate to think of the consequences. So take a little time and make sure your equipment is safe.

4. Compaction may be an issue for you. I pull a 250 bushel air cart and a 1500 gallon ammonia tank without too many problems other than I was stuck between 25-30 times last spring. It's really hard to back up a unit that bends in five places. So forward is the only way out. My ammonia tank tires track between the front and back airseeder wheels and happened to run between drill rows as well. And even with last year's extreme wet conditions I had very few places that compaction seemed to be a problem. In fact the crop actually looked better in the wheel tracks, telling me I didn't have adequate packing on the seed rows. Since then I have purchased new packer wheels for the drill. Options for you to consider would be oversized wheels for your ammonia tank, which may be too expensive, approximately $20,000 plus a whole bunch of wiring to reach all your monitors. Couldn't we have fun farming if we had an unlimited supply of disposable income?

Like I say, I'm far from having all the answers, but this is what I've been doing. The one thing I've found though is that you have to be flexible. What works this year might not work for you next year or what I do may not work for you. All of our farms are a little different. We don't all have the same equipment combinations or soil conditions or even the same philosophy of what's right. Lord knows that our weather conditions aren't the same every year so we have to be able to go with the flow as well as not worry so much what your neighbors might be saying about you. It really doesn't matter that much. Like they say "if nobody's talking about you, check your pulse".

Two years ago I tried seeding wheat into a fescue crop that was seeded the year before. I saw no reason why it shouldn't work, but after making three rounds I gave up. The fescue had become too established and had used the majority of the moisture up. I couldn't keep the drill in the ground and I had no control of seed and fertilizer separation. Last year I had the same scenario but the fescue was barely showing. There was lots of moisture and my biggest fear was getting stuck. I had a nice crop of wheat and the fescue stand looked excellent last fall. I was also able to seed barley into sod that I chem fallowed the year before and the barley looked better than on the rest of the field.

It's not that zero-till is so hard to do it's a matter of getting at it. It's been said that you have to break the friction between your butt and the chair. The equipment is available and there are lots of knowledgeable people out there to talk to. Every year we see something new and exciting and we can't wait until it's perfect or we'll be waiting forever. I thought I had my outfit perfect, but now I'll probably add a third tank to my airseeder so I can put on granular inoculant with my peas.

Something I should touch on is spraying. Spraying is a very important operation in a zero-till or even minimum till farm. Timing is quite important and we probably tend to spray more acres than our conventional till neighbor. When I bought the Harmon drill on 12 inch spraying my fields were a little rougher than I had expected and our old conventional sprayer couldn't quite take the abuse we were putting it through. So last year I bought a 60 foot Computerspray with a fifth wheel hitch. I pull it with a GMC 4WD one ton pickup. I chose the twin line option which lets me travel 20-25 mph. The automatic transmission is real nice for wet spots because you don't have to manually shift before you get stuck. Because last spring was so wet I bought some 33 inch mud tires and ran at about 20 psi for flotation and it also made the ride a little smoother. Being able to spray a quarter in an hour and a half and to be able to move to the next field at 50 mph saved me a lot of time last spring. Remember that in zero-till your fields can be a lot rougher and the computerspray uses suspended booms making it possible to travel at these speeds.

I think that the amount we use our sprayers in zero-till and the added benefits of timing warrant buying a good sprayer. What you choose is your choice. Personally I chose this sprayer for speed, ease of use and being able to use low water volumes (1.34 gallons for my burn off). Though the high speed helps control drift use caution with low water volumes—I speak from experience. I kind of did a preharvest burn off in June for my neighbor across the fence.

You seem to end up with different weed problems with zero-till, not necessarily worse problems but different. The main ones probably being narrow leafed hawksbeard, common groundsell and dandelions. It seems that some of these weeds are problems now but timing of spraying has a lot to do with the severity of the problem. I've found that you don't want to let a field get ahead of you before seeding. Even if it might mean spraying a certain field twice before seeding you'll be better off than trying to kill large hawksbeard or dandelions. But times are a changing and we are bound to see new chemicals that will fit better into zero-till operations.

Something that I won't spend much time on is chaff spreaders. To make it short, you need one. There are lots of different kinds available and some work better than others. I'm very happy with my Kirby spreader by Dutch Industries on my Claas 108. On a calm day it will spread up to 60 feet though the wind will affect it.

I'll kind of wrap things up with a point of interest. With my drill being on 12 inch spacing it tends to leave fairly deep seed rows approximately 3-4 inches. We noticed that if we seeded NW-SE the seedlings got maximum use of available sunlight—meaning that the rows warmed up faster in the morning. The seedlings were also protected in this little micro climate from prevailing winds. How much benefit this gives the plant I don't know but I give it consideration

when I am choosing seeding direction. Angle seeding has its benefits when on 12 inch seeding at swathing time. Though I try to straight cut as much as possible years like last year are bound to come along once in a while, and it is nice to keep the swath from falling on the ground.

Well that's about it. I'm sure that in about 20 minutes I'll think of something I should have said, but I probably covered the basics. I hope I shared something of value with you and maybe we can get together and compare notes in the future. We live in a time of ongoing change and meetings like this one give us the chance to help each other out the best we can. I'm actually looking forward to another year now that I'm finally starting to get last year out of my system. Hopefully I'll actually be able to seed a whole quarter section without getting stuck, and a 40 bushel crop of #2 wheat that is standing up will be a pleasure to harvest dry. Please don't be shy about asking me any questions. I'll do my best to answer them for you. And remember when you're looking over your neighbor's well cultivated field and every row looks neater than the next, the grass is always greener over the septic tank.

Integrated Weed Management in Reduced Tillage Systems

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Introduction

The concept of integrated weed management (IWM) has been around for a long time but has not been taken very seriously. One of the main reasons for this is that herbicides have generally proven to be a very effective and relatively non-laborious means of controlling weeds in corps. In recent years, however, the development of weed resistance to herbicides has cast doubt on the sustainability of depending too much on this "magic bullet" approach to weed management. In western Canada, some of our most serious weeds (including wild oats, green foxtail, chickweed, kochia, wild mustard) have become highly resistant to one or more of several classes of herbicides with which they were once controlled. This more than any other issue is spearheading the move towards more integrated approaches to weed management.

Traditionally, tillage and summerfallow have been integrated with herbicide use as a means of weed control. Producers adopting reduced or zero tillage systems can no longer depend on these practices as components of an IWM system. These producers have to re-examine the concept of IWM and combine other agronomic principles with herbicide use if their weed management systems are to be effective and sustainable.

IWM can be defined as a system of sustainable weed management that combines rational and judicious herbicide use with other principles and practices in order to reduce the impact of the weeds to an economically acceptable level. While many of the principles discussed in this paper apply to both conventional and reduced tillage systems, they have particular application in situations where tillage is reduced or eliminated.

Components of an IWM System for Reduced Tillage Systems

The goals of an IWM system should be to reduce the movement of weed seed into the soil and to reduce the impact of weeds on crops to an economically acceptable level . The emphasis should be on management rather than eradication, since many years of continuous herbicide use have failed to eradicate weeds from soil seed banks.

An important first step in an IWM program is to prevent the movement of weeds into the field. This can be achieved by planting clean seed, cleaning tillage and harvesting equipment between fields, tarping grain trucks, avoiding transfer of soil from roadsides to crop land, and controlling weed infestations along roadsides, fence rows and waste areas. Perennial weeds such as quack grass, Canada thistle, perennial sow-thistle, toadflax and foxtail barley growing along the perimeters of fields in reduced tillage systems can rapidly encroach into the field if allowed to do so. The success of an IWM system for reduced tillage will be influenced considerably by the proper management of weeds in these non-crop areas.

While prevention and sanitation are very important components of an IWM system, virtually all farmers already have weed seeds present on their land. A number of factors will influence how effectively these weeds are managed, and how much weed seed is returned to the soil. These include the type of direct weed control methods employed such as the use of synthetic herbicides or biological control agents, and agronomic weed management practices such as crop rotation. The essence of an effective IWM system is to combine one or more of these practices with strategies that maximize the competitiveness of the crop relative to the weeds. These include planting vigorous, high quality seed, growing competitive crops and cultivars, promoting early crop emergence, choosing optimum crop row spacings and seeding rates for weedy situations, and placing fertilizer to favour the crop.

Biological control methods may be a feasible option in the future. At present biological control with insects is proving successful in some non-cropping situations (e.g. leafy spurge flea beetle), but there is nothing available for situations where crops are grown intensively. Similarly, there are no mycoherbicides (based on plant pathogenic organisms) currently registered in Canada, and it is unlikely that this will change in the near future. The rest of this paper will therefore focus on the integration of herbicides with agronomic practices that favour the growth and development of crops relative to weeds.

Use Herbicides Judiciously

Herbicides can be the most important but should not be the only component of IWM for reduced tillage systems. If spring tillage is eliminated, a pre-seeding burn-off with a non-selective herbicide (e.g. Roundup® at 0.45 L/acre+350 ml surfactant/100 L water) may be necessary. This will control most annual weeds and suppress winter annuals. Effective quack grass control may also be obtained at this rate if environmental conditions are optimal and the weed is actively growing.

When fall tillage is eliminated, winter annuals such as stinkweed, shepherd's purse, flixweed, bluebur and narrow-leaved hawk's beard tend to increase. Fall is the most appropriate time to control these weeds. MCPA or 2,4-D at 6-8 oz. active per acre is a very cost-effective treatment. Hawk's beard is somewhat more tolerant and requires 10 oz. per acre. These weeds are more susceptible to herbicide applications in the fall than in the spring. A study conducted at Scott, SK showed that considerable stinkweed and flixweed biomass remained following spring herbicide application, whereas fall control virtually eliminated the weeds (Table 1).

Table 1. Effect of application timing on dry weight (gm/m^2) of stinkweed and flixweed in winter wheat. Weeds were collected and weighed in late June.

Application time	Stinkweed	Flixweed
Untreated	122	40
October 27	0	0
May 13	35	43

Source: K. Kirkland, Agriculture and Agri-Food Canada, Scott, SK.

The risk of crop injury due to residues of these herbicides will also be considerably less if winter annuals are controlled in the fall rather than the spring.

Management of perennial weeds such as quack grass, Canada thistle, sow-thistle and toadflax is also best accomplished in the fall. In the spring, waiting for sufficient regrowth to maximize herbicide efficacy can delay seeding and result in reduced crop yields. Early competition from these weeds in the spring can also reduce crop yields.

One of the problems associated with fall perennial weed control, especially post-harvest, is the risk of reduced efficacy due to frost and cold temperatures. At least 2 weeks of frost-free weather is recommended after herbicide application. Effective fall control of perennial weeds has become much more feasible with the recent registration of pre-harvest Roundup® (1 L/acre). The treatment is registered for wheat, barley, canola, pea, dry beans lentils and flax. It is not recommended for crops grown for seed. The grain should contain 30% moisture or less (7 to 14 days before harvest). Comparisons of pre-harvest compared to post-harvest Roundup® application is presented for quack grass (Table 2). Pre-harvest application was generally more effective and more consistent.

Table 2. Quack grass control (%) with pre-harvest compared to post-harvest Roundup® (1 L/acre). Ratings were taken 1 year after treatment.

Application	Mean	Range	Consistency
Pre-harvest	94	75-99	94
Post-harvest	86	50-99	78

Source: M.N. Baig, Monsanto Canada Inc.

The use of pre-harvest Roundup® was the key factor in managing toadflax under zero tillage. After one application toadflax dry weights were reduced considerably by Roundup® at 0.5 L/acre (Table 3).

Table 3. Effect of pre-harvest Roundup® on toadflax dry weight in a barley/canola/barley rotation.

Glyphosate rate (L/acre)	Toadflax dry weight (g/m^2)	
	Fall 1994	Fall 1995
0	108	108
0.5	18	1
1	5	0

Harker, O'Donovan and Blackshaw (unpublished).

Further reductions occurred at 1 L/acre. After two applications, toadflax control was as effective at the low as at the high rate. Crop yields were also increased following application of the herbicide (data not shown).

In-crop weed control in the spring may or may not be required. Special attention should be paid to weed economic thresholds and herbicides should be used only when necessary. Every effort should be made to avoid the development of resistant weeds. Refer to the publication "Resistance of weeds to herbicides" prepared by the western Canadian provincial departments of agriculture. Rotate among the herbicide groups listed in the publication. For example, do not use wild oat herbicides of the same group more frequently than one year in three. Following this practice is especially important in reduced tillage systems, where herbicide use may increase in the short term. It is also important to realize that rotating herbicides is just one strategy in the battle against resistance. Effective, long term weed management is best achieved by paying attention to some of the agronomic principles discussed below.

Grow Competitive Crops in Appropriate Crop Rotations

Several studies suggest that including competitive crops and cultivars in a rotation, and combining appropriate crop rotations with herbicides can reduce the effects of weeds on crop yield and weed populations over time. Of the principle field crops grown in western Canada, barley is the most competitive followed by canola and wheat. Crops such as flax, peas and lentils are considerably less competitive with weeds. As indicated in Table 4, the effects of weeds on crop yield will be considerably less in barley than in most other crops.

Table 4. Effects of wild oats (100/m^2) on % yield loss of various crops.

Crop	Crop yield loss (%)
Barley	23
Wheat	34
Canola	32
Flax	60

Adapted from Dew (1972)

The effectiveness of barley in reducing the build-up of wild oat populations over time is illustrated in Table 5.

Table 5. Wild oat population changes as influenced by cropping system.

Crop rotation	Wild oats/m^2			
	1983	1984	1985	1986
Continuous wheat	8	71	162	271
Continuous barley	11	5	23	42
Canola/barley	11	28	118	43

Adapted from O'Donovan (1988)

The increase in wild oat populations over 4 years was considerably less in continuous barley and the canola/barley rotation than in continuous wheat (Table 5).

This study illustrates how problem weeds are often associated with a particular crop (e.g. wild oats in wheat). As well as being less competitive, wheat also takes longer to mature than barley (or Polish canola) thus giving wild oats ample opportunity to produce plentiful amounts of viable seed. Appropriate crop rotations can also minimize weed problems by maximizing control options. Rotating non-cereal with cereal crops can maximize herbicidal control of serious grass weeds such as wild oats and quackgrass. For example, in a 6 year field experiment in Idaho, the use of herbicides reduced wild oat populations in the soil by 41% in a winter wheat-spring barley-spring pea rotation compared to only 21% in continuous winter wheat (D. Thill, University of Idaho, Moscow, unpublished). In experiments conducted under reduced tillage in Saskatchewan, rotations of spring and winter wheat with mustard or flax, together with herbicide use, reduced quackgrass shoot populations from 800-1200/m^2 to 0-200/m^2 in 4 years (Loeppky and Derksen 1994). This study suggests that where appropriate crop rotations are combined with herbicides, quack grass may become less problematic over time in reduced tillage systems.

Plant Vigorous Seed and Promote Early Crop Emergence

A very important first step in an IWM system for reduced tillage is to plant vigorous high quality seed. This is crucial during the first few weeks of establishment when the crop and weeds are competing vigorously for moisture nutrients and light. Research conducted at the University of Manitoba (E. Stobbe) showed that crop seed size can make a big difference during early crop establishment. Large seed was considerably more vigorous than small seed and thus promoted early crop emergence.

Numerous studies have shown that crops that emerge early compete better with weeds, suffer less yield losses, and less weed seed is returned to the soil. In a study conducted at Vegreville, AB, wild oats that emerged a few days before the crop caused substantial yield losses, whereas those that emerged a few days after had little effect on crop yield (Table 6).

Table 6. Effect of relative time of emergence of wild oats (20 plants/m^2) on yield loss of barley and wheat. DB = days before crop, DA = days after crop, ST = same time as crop.

Relative time of wild oat emergence (days)	Crop yield loss (%)	
	Barley	Wheat
5 DB	17	19
3 DB	13	15
1 DB	9	13
ST	8	11
1 DA	6	10
3 DA	4	8
5 DA	3	7

Adapted from Cousens et al. (1987)

Green foxtail is considerably less competitive than wild oats. Even at very high densities its effect on crop yield can be strongly influenced by the time it emerges relative to the crop. Studies at Vegreville have shown that when barley or wheat emerged a few days ahead of green foxtail, crop yield losses were minimal, even at green foxtail densities of several thousand plants/m^2 (O'Donovan 1994a).

By striving to ensure that crops emerge as early as possible ahead of weeds, producers can minimize crop yield and financial losses due to weeds. Early crop emergence can be promoted by planting vigorous crop seed at relatively shallow depths when the seed bed is moist and firm (as is often the case in zero tillage systems). The crop can also be given an advantage by seeding as soon as possible after the last tillage operation in a conventional tillage system, or pre-seeding herbicide application in a reduced tillage system. Otherwise, weed seed present in the soil may begin germinating even before the crop is planted. Weeds that emerge late relative to strong competitive crops such as barley may not require in-crop control with herbicides. Omitting herbicide application in these situations could result in considerable monetary savings, and would delay or prevent selection of herbicide resistant weed biotypes.

Establish a Good, Vigorous Crop Stand

Crop density (stand) can strongly influence the competitive effects of weeds, and the yield and financial losses caused by weeds. In many cases, recommended crop seeding rates have been developed based on weed-free situations. Where weeds are present and where herbicide use may be limited, increasing the crop seeding rate can increase crop yield and reduce the amount of weed seed returned to the soil.

For some weeds in canola (e.g. Tartary buckwheat, stork's bill, cleavers and corn spurry), there are few if any post-emergence herbicides available. Research conducted at Vegreville suggests that relatively high canola seeding rates can reduce the competitive effects of Tartary buckwheat (O'Donovan 1994b). Where no Tartary buckwheat was present, there was little advantage to increasing the number of canola plants per unit area. However, where the weed was present, canola seed yield increased and Tartary buckwheat seed yield decreased with increasing canola density (Table 7).

Table 7. Effect of Tartary buckwheat (50 plants/m^2) on canola and Tartary buckwheat seed yield at various canola densities.

Canola plants/m2	Canola seed yield (g/m^2)	Weed seed yield (g/m^2)
25	110	23
50	135	15
100	150	10
200	165	5

Adapted from O'Donovan (1994b)

The results suggest that a canola density of 200 plants/m^2 provides the crop with a considerable advantage over weeds compared to lower canola densities (e.g. 50-100 plants/m^2). Relationships between canola seeding rate and plant density can be difficult to determine especially under western Canadian dry land conditions. However, based on these results, in most cases a seeding rate of at least 8 kg/ha would be required for maximum weed suppression.

The above, and most other experiments designed to determine the influence of crop seeding rate on crop/weed interactions have been conducted in conventional tillage systems. There is little similar information available for reduced or zero tillage systems. An experiment was conducted at Vegreville AB from 1994 to 1996 to investigate the effects of different barley seeding rates on competition from wild oats in a zero tillage system. The results indicated that the extent of the yield loss due to wild oats was less at the higher barley seeding rates (Table 8). Yield loss due to wild oats was least in 1995 (the driest year) and highest in 1996 (the coolest year) (Table 8).

Table 8. Percentage barley yield loss due to wild oats at various barley seeding rates in a zero tillage system.

Barley seeding rate (kg/ha)	% yield loss			
	1994	1995	1996	Average
50	36	15	69	40
100	26	16	41	28
150	28	13	42	28
200	21	8	28	19
300	22	7	27	19

O'Donovan, Harker and Blackshaw (unpublished)

Each year, wild oat seed production decreased as barley seeding rate increased (Table 9).

Table 9. Effect of barley seeding rate on wild oat seed production in a zero tillage system.

Barley seeding rate (kg/ha)	Wild oat seeds/m^2		
	1994	1995	1996
50	1200	1160	3880
100	600	520	2800
150	400	320	2600
200	320	200	1920
300	200	120	1320

O'Donovan, Harker and Blackshaw (unpublished)

Averaged over the three years, wild oat seed numbers dropped by about 130% when the seeding rate increased from 50 to 300 kg/ha. Increases in spring wild oat plant populations between 1994 and 1996 were greater at the lower barley seeding rates. For example, at a seeding rate of 50 kg/ha, the wild oat population increased from 80 plants/m^2 in 1994 to 235 in 1996, whereas at 200 kg/ha the population remained constant at 80 plants/m^2 from 1994 to 1996.

The study showed that, in most cases, yield losses were greatest at the lowest barley seeding rate (50 kg/ha). Averaged over all wild oat densities, yield loss from the wild oats lessened as barley seeding rate increased up to 200 kg/ha. There was no yield advantage to seeding at 300 kg/ha. In fact where no wild oats were present (weed-free checks) yield tended to decrease at the highest seeding rate, especially during the dry year (1995). The recommended seeding rate for barley in the thin black and black soil zones is 86-144 kg/ha. Our study suggests that for optimum wild oat management and crop yield in zero tillage systems, barley should be seeded at the high end of this range or higher, but should not exceed 200 kg/ha. Seeding at a relatively high rate in areas of the field where wild oats and other weeds occur at high infestations (e.g. low spots) may be more feasible than seeding at a high rate over the whole field.

It is unlikely that increasing the seeding rate alone would be sufficient to manage wild oats or other weed populations over the long term in a zero tillage system. A combination of limited herbicide use and relatively high seeding rates would be a more feasible approach. Herbicides would almost certainly be required during some years, particularly pre-seeding applications for weeds that emerge prior to seeding. No herbicides were used over the course of this study since the focus was on determining effects of seeding rate only. Wild oat populations were relatively heavy, and crop yield losses were unacceptable in 1994 and 1996, even at the higher barley seeding rates. Wild oat competition was strongest in 1996 when the spring was cool and wet, and weakest during the relatively dry and warm spring of 1995. This suggests that wild oats may not be as much of a problem in zero tillage systems under relatively dry soil conditions, and may not require control with herbicides, especially at high crop seeding rates. Seed production by wild oats is also likely to be much less under these conditions.

Will Narrower Crop Row Spacings Reduce Weed Competition?

The results of an experiment conducted at Scott, SK under conventional tillage show advantages to reducing barley row spacing (Kirkland, 1993). Weed biomass (wild oats, wild mustard and volunteer canola) increased and barley seed yield decreased as row spacing increased from 11 to 46 cm (Table 1). These results indicate that wider crop row spacings may promote weed competition and decrease crop yield in the absence of herbicides.

Because of crop residue problems, decreasing row spacing to manage weeds may be less feasible in conservation tillage systems. On the contrary, the trend is to increase row spacing from the more common 22 cm to 33 cm. In this study (Kirkland, 1993), increasing the row spacing to 33 cm resulted in a 13% decrease in barley yield and a 34% increase in weed biomass. It is possible, however, that the increased weed competition at the wider row spacing resulted more from a reduction in barley plant populations per unit area (see shoot counts in Table 10) rather than from a direct effect of the wider spacing. Thus increasing the crop seeding rate to maintain

high plant populations at the wider row spacings may enhance the competitiveness of the crop and alleviate the negative effects of the weeds on crop yield.

Table 10. Effect of barley row spacing on competition from weeds.*

Barley row spacing (cm)	Barley** shoots/m^2	Barley yield (g/m^2)	Weed biomass (g/m^2)
11	805	350	300
22	550	300	710
33	380	260	1080
46	270	200	1205

*Data are averaged over different barley seeding rates and years.
**Numbers represent tillers rather than plants.
Adapted from Kirkland (1993).

In other studies under conventional tillage, similar crop densities per unit area were maintained among row spacings, and there was little difference in yield of barley seeded in 9 or 18 cm rows (Barton et al. 1991) or canola seeded in 10 or 20 cm rows (O'Donovan 1994b). Slight increases in weed biomass occurred at the wider row spacings in both studies but this was not sufficient to have a major effect on crop yield. Similarly, in spring wheat seeded under no-till, wild oat plant counts and biomass did not differ between 20-, 30- and 40-cm spaced rows (Reinertsen et al. 1984).

Place Fertilizer to Favour the Crop over the Weeds

Both crops and weeds compete for nutrients (e.g. nitrogen, phosphorus) present in the soil. There have been a lot of studies conducted over the years to try and determine if the addition of extra nitrogen or other nutrients can reduce competition from weeds. The results have not always been as expected. In many cases added nitrogen actually benefited the weed over the crop. For example, in experiments conducted in California, wild oats were better able to utilize added nitrogen than wheat, and therefore gained a competitive advantage over the crop (Carlson and Hill, 1986). In a more recent study, researchers at North Dakota State University reached a similar conclusion with green foxtail (wild millet) (Peterson and Nalewaja, 1992). Doubling the nitrogen rate did not increase wheat growth, but increased green foxtail weight by 41%.

Does this mean that nitrogen will always benefit weeds over crops? Apparently not! Results from a study conducted in northeaster Alberta tell a very different story (O'Donovan, McAndrew and Thomas, unpublished). Evidently, *how* the nitrogen is applied can make all the difference in terms of whether the crop or weeds benefit.

The effects of tillage and nitrogen on green foxtail populations present above-ground in the spring, and in the seed-bank in the fall are presented in Table 10. Herbicides used to control green foxtail and broadleaved weeds were Hoe-grass II® (1989, 1990, 1991) and Stampede 360

plus MCPA® (1992). The results are very different from the U.S. studies referred to previously. Not only did the addition of nitrogen dramatically reduce green foxtail populations, but the populations tended to decrease as nitrogen rate increased. Furthermore, green foxtail populations were reduced more under zero than conventional tillage. Stinkweed populations also decreased as nitrogen rate increased.

Why the big difference between our results and those from the U.S.? In the U.S. studies the nitrogen was broadcast and soil-incorporated. Thus the weeds and crop had equal access to the nutrient. In our study, however, the nitrogen (urea) was banded 10 cm deep in 40 cm spacings, while phosphorus was applied with the seed. This provided an advantage to the crop which was able to access the nitrogen and phosphorus much more readily than the shallowly rooted green foxtail.

Table 10. Effect of banded nitrogen and tillage on green foxtail populations. Data were averaged over 1991 and 1992.

Banded nitrogen (kg/ha)	Conventional tillage		Zero tillage	
	Green foxtail plants			
	Emerged/m^2	Seedbank/kg soil	Emerged/m^2	Seedbank/kg soil
0	205	77	113	67
60	42	16	14	7
120	31	14	3	2
180	14	10	3	2

O'Donovan, McAndrew and Thomas (unpublished)

A related study (Blackshaw et al. 1996), showed that an integrated management approach that included banding nitrogen may allow producers to manage foxtail barley successfully in conservation tillage systems. Roundup® applied preharvest, postharvest or preseeding reduced foxtail barley biomass but did not eliminate the weed. Increasing wheat seeding rate reduced foxtail barley biomass and increased wheat yield by 16 to 32%. Finally, deep banding compared to surface broadcasting nitrogen reduced foxtail barley biomass and increased wheat yield up to 58% (Table 11).

Other studies suggest that banding nitrogen may also favour crops over wild oats. In wheat growing under zero tillage, there were 27-57% less wild oat plants when nitrogen fertilizer was band-applied in the seed row compared to broadcast-applied prior to seeding the wheat (Reinertsen et al. 1984). Similarly, in spring barley, there were 28-60% less wild oat shoots when nitrogen fertilizer was band compared to broadcast-applied (Lish and Thill, University of Idaho, Moscow, unpublished).

Table 11. Effect of banded vs broadcast nitrogen on foxtail barley biomass and wheat yield.

Nitrogen rate (kg/ha)	Nitrogen placement	Foxtail barley biomass (g/m^2)	Wheat seed yield (g/m^2)
0	Banded	162	94
	Broadcast	197	83
60	Banded	276	114
	Broadcast	297	99
120	Banded	286	179
	Broadcast	397	113

Adapted from Blackshaw et al. (1996)

These studies indicate that banded nitrogen can be an important component of an integrated weed management system. The strategy was especially effective for green foxtail management under zero tillage. Above-ground populations were reduced to 2 or 3 plants/m^2 at the higher nitrogen levels (Table 9). These low infestations would have virtually no effect on crop yield, and would not be expected to replenish the soil seed-bank to a great extent since a large proportion of the seed produced was in the surface residue. Dependence on herbicides for green foxtail control may therefore be reduced resulting in less selection pressure for herbicide resistance and greater savings for producers. These studies clearly show how integrating herbicide use with sound agronomic practices can be far more effective than herbicide use alone.

Summary and Conclusions

Farmers adopting reduced or zero tillage systems of crop management do not need to become over-reliant on chemical herbicides for weed control. To do so could lead to selection of weed biotypes that are resistant to herbicides, especially where herbicides of the same mode of action are used continuously. While it is true that reducing or eliminating tillage can result in short-term increases in some weeds (notably perennials and winter annuals), long term weed problems in reduced tillage systems can be alleviated considerably by integrating control practices with sound agronomic principles and practices.

An important first step in an IWM program is to prevent the movement of weeds into the field. This can be achieved through proper sanitation, and by controlling weed infestations (especially perennial weeds) along roadsides, fence rows and waste areas. Then it becomes a question of managing the weeds already in the field. The emphasis should be on managing weeds to an economically acceptable level rather than weed eradication, since it is becoming increasingly evident that continuous herbicide use will fail to eliminate weeds from a field.

A more rational approach would be to integrate herbicide use with practices that maximize the competitiveness of the crop over the weeds. Planting high quality, vigorous seed of competitive

crops in appropriate rotations, and manipulating factors such as crop seeding rate, row spacing and fertility placement to favour the capture of resources by the crop can reduce the impact of weeds on crop yield and reduce the amount of weed seed entering the soil. Adopting agronomic practices that ensure early emergence of the crop relative to the weed can also confer a major advantage to the crop. For example, planting crops relatively shallowly into a moist and firm seedbed as soon as possible after a pre-seeding herbicide application will likely result in the crop emerging ahead of the weeds with minimal impact in terms of crop yield loss and weed seed production. Each of these practices when considered alone may not be sufficient to provide adequate weed management. However, combining these practices and integrating them with judicious herbicide use will result in long-term, more cost-effective and sustainable weed management systems for reduced tillage systems compared to where herbicide use is the dominant or sole weed control practice.

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Direct Seeding of Peas into Fescue Stubble
1996 Crop Year

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Background of Project 1995

The Fairview Applied Research Association and farm cooperator Ron Doll designed and implemented an interesting project of direct seeding peas into fescue sod. A few variables affected their plot but the results still were satisfactory in producing a 30 bushel pea crop. Several farmers and groups toured this site and Dan Lane's interest was piqued. (Aroused or stirred up.)

Dan planned to get into direct seeding as a way to speed up his seeding operation. In 1995 he had four quarters in second year fescue. The vegetation was very thick and there was no point in trying to go for a third seed crop. Dan decided to try direct seeding on 505 acres. Two quarters were close together (NW 9 - 78 - 2 West of 5th called field #1 which is about 150 acres; NE 6 - 78 - 2 West of 6th field #2 is about 135 acres; SW 4 -78 - 4 West of 6th field #3 and the NE 4 - 78 - 4 West of 6th called field #4 for the remaining 220 acres).

Operations
In 1995 -

Fescue harvest was completed early in August and sprayed with one litre per acre of Roundup on August 9, 10 and 11. I inspected with him one month later. On September 9 there was little evidence of plant dieback. The crop grew to about one foot in height and there was a lot of organic matter present.

During November an application for funding was made to the Pulse Growers Association to monitor the four fields and to record the data. The request for funding was routed through acting Pulse Specialist David Wong and the request was denied by the Pulse Growers in March of 1996.

We (FARA and myself) suggested there were savings to be made in direct seeding peas in our funding request. Tillage required to renovate a sod bound fescue crop - one plowing @ $15.00, two discings @ $13.00 each or $26.00 plus two cultivations @ $5.00 or $10.00 -- for a total of $51.00 per acre savings. Dan planned to seed about May 7 to 10 in the spring of 1996. He thought of applying another 1 litre of Roundup prior to pea emergence.

We made some of the following assumptions in the fall of 1995.

Direct seeding of peas into fescue stubble should test the following:

- Flotation for seeding equipment planting on sod in wet areas.
- More available spring moisture to germinate peas
- Colder soils which will delay germination, to allow a spring application of Roundup.
- Roundup preemergent to control spring germinating weeds.
- Fescue aftermath and pea growth to provide competition to spring and summer germinating weeds.
- Fewer weeds will promote more crop growth.
- Very little tag (dirt) as the peas will not be in contact with soil.
- A better quality grade should result.
- A better return per acre due to less cost for preparing the land with tillage.

This information would be of benefit to the Pulse Growers Association and so we thought they would fund our project.

The fall of 1995 was wet, harvest was difficult in the Wanham area, pea swaths were so heavy and moist that Shane Farms had trouble getting peas off the swather table. Several models of swather were tried but the results were the same. Only a partial swath would slide off the table. The ground was wet and cultivation was difficult but it could have occurred after harvest before freeze up.

Over the winter Dave Ross Equipment modified a 30-foot John Deere Air Seeder with Barton openers. Cost of 40 openers x $750 each = $30,000 plus labour.

The spring of 1996

There was a lot of snow melt and the ground was moist to saturated.

Dan tested the modified seed drill before he was ready to plant. There was a thick mat of organic matter from the previous year's fescue regrowth covering the ground surface. The Barton openers would not penetrate the soil properly.

This caused a change in plans.

Dan disced around each of the three fields, got a fire permit, lit a few matches and stood back.

Dan sprayed Ally (sulphonyl urea) on the fescue in 1994 and 1995 for broadleaf weed control. He was concerned about herbicide carry-over affecting pea germination in 1996. He wanted to spray Roundup on the field before the peas emerged to kill the fescue.

But I ran this scenario by him—after burning you have a lot of carbon and ash on the ground. The carbon will (hopefully) deactivate any herbicide in the soil. You won't be able to spray

Roundup because the ash and carbon particles will neutralize (adsorb) the herbicide.

Dan seeded the fields #1 and #2 on May 11, 12, 13. This was close to his target of May 7 to 10. He was on these fescue fields 10 days before he started conventional minimum tillage seeding on the rest of his farm. He seeded fields #3 and #4 on May 15 and 16 and they were cold and wet.

Note: Other farmers applying anhydrous at this time were having problems with openers freezing off.

Dan seeded 500 bushels of Certified Carneval and the rest was planted to common (Carneval) peas from 1995 production on his own farm. Carneval is an AWP variety and is classed as a semi-leafless, medium-early, medium-sized, smooth-yellow, with good resistance to lodging.

The peas were planted two to three inches deep at three bushels per acre. The ash and carbon were so thick in the air that you could hardly see the air seeder when planting. At this time Dan gave up the idea of spraying Roundup before the peas emerged.

The peas emerged in 6 days.

There are several pictures taken over the growing season. They are presented at the Direct Seeding Workshop but are not reproduced here.

Field #1 -

First seeded - not all of the 3 bushels planted stayed in the ground. There was lots of fescue regrowth. Weeds like toad flax, cleavers, Canada and Sow thistle and a few wild oats started growing. Too late to spray - 6th node and higher when we inspected the crop on June 13. Reglone was custom applied on August 27. Combined September 12 and 13. This is 16 days after Reglone application. The crop was ready earlier but rains delayed harvest. Remember how many farmers were cutting ruts in their field in the fall of 1996 or the ground was so saturated that farmers could not swath or combine. Well these fields were easy to combine. So this was an added benefit to leaving the sod. The field produced 60 bushels per acre.

Field #2 -

Second seeded - less seed on surface than field #1. Fescue regrowth less than field #1. But note in the picture the effect of a spray miss. Too late to spray on June 13. Reglone applied on August 27. Combining started September 18, about 22 days after Reglone application. There were rainy periods during this time. This field ran an estimated 65 bushels per acre. Both fields ended up averaging 60 bushels per acre when the crop was dried and sold.

Fields #3 and #4 -

The third fields seeded. This field has the most soil problems - solenezic - and so has internal drainage problems. This field was wetter when seeded. There was a lot of peas on the ground

surface. We think that the clay stuck to the Barton openers and the pea seed was flipped up on the surface. Roundup fall applied to kill weeds and fescue regrowth. The crop was thin enough that if Reglone was used it would have been a waste of money. Combined on October 10. Several showers between Roundup application and combining. This field ran 15 bushels per acre. It is interesting to note that the pea growth was exceptional around the outside edge of the field in the fire guard disced area. Dan estimates the yield was 45 bushels in this disced strip.

Custom seeded another 160 acres of peas with the same equipment (NO COMMENT).

Conclusions and evaluations about direct seeding peas into fescue sod.

Other direct seeding peas into fescue experiments did not do well this year. Seeding into cool, wet soil with a lot of organic matter on the surface kept the peas from growing properly. Direct seeding experiments were a bust on the north side of the Peace. Dan might have been lucky in that he burnt, turning the fields black. This perhaps warmed up the soil and resulted in two great yields out of four fields.

Peas sold at $5.60 per bushel. Dan kept 2400 bushels for seed.

Estimate of gross return:
(135 acres x 60 bu)+(150 acres x 60 bu)+(220 acres x 15 bu) = 8100 + 9000 + 3300 = 20400 bu
18000 bu x $5.60 = $100,800.00
2400 kept as seed (value $6.50) = $15,600.00
A total of $116,400 from 505 acres or $230.50 per acre

Food grade - did not try for food grade. Dan delivered the peas to Cargill in Rycroft. The peas were dried and sold right then.

Testing our assumptions made the year before seeding.

Direct seeding of peas into fescue stubble should test the following:

Flotation for seeding equipment planting on sod in wet areas.

Yes, Dan was on these fields 10 days before he could get on other land to direct seed. He could seed through the entire area and did not have to miss low spots.

More available spring moisture to germinate peas

Moisture was available in the spring - it dried out and then got wet. The sod probably allowed better water penetration and helped prevent ponding and erosion.

Colder soils which will delay germination, to allow a spring application of Roundup.

This did not work - peas were up in six days and the carbon from burning would have deactivated a large percentage of the Roundup.

Roundup preemeregent to control spring germinating weeds.

The peas emerged quickly. The fescue was only at one to two green-leaf stage so there was not a lot of leaf area to pick up herbicide.

Fescue aftermath and pea growth to provide competition to spring and summer germinating weeds.

Definitely, the weeds were held back by the sod not being broken. There were some surface germinated weed. Fescue did grow more thickly in fields #3 and #4 where peas were thinner due to seed not being placed in the soil.

Fewer weeds will promote more crop growth.

Dan did spot spraying for thistle on fields #3 and #4. Not enough competition from peas to hold down perennials.

Very little tag (dirt) as the peas will not be in contact with soil.

Dan indicates that these were the cleanest peas he combined in three years of harvest. The sod definitely helped keep peas out of the dirt. The fields #1 and #2 were straight combined. Fields #3 and #4 were swathed because of the light crop.

A better quality grade should result.

They were sold as feed peas, he did not try for food grade.

A better return per acre due to less cost for preparing the land with tillage.

A definite yes. A savings of $51.00 per acre in cultivation costs x 505 acres = $25,755.00 saved in 1995. It did cost over $30,000 to put Barton openers on the drill. Dan modified the drill after seeding - this consisted of realignment of openers to provide uniform direction and spacing of openers, placed all at a 9-inch space and each cuts in the same direction now. The 9-inch space will work well for peas, canola and cereals and an 18-inch spacing is recommended for tall fescue production.

Other benefits that we did not consider.

The fescue regrowth on fields #1 and #2 is excellent. There is about one plant per square foot which should produce an excellent crop of fescue in 1997. Dan did not fall fertilize these fields. The pea roots should make nitrogen available to fescue over the 1997 crop year. Any supplemental addition of nitrogen might cause the fescue stand to produce excess vegetation

rather than seed production. A broad leaf spray will be used to control toadflax and thistle.

Fields #3 and #4 were fall Roundup'ed to kill of the weeds and regrowth fescue. There was no tillage in 1996. These fields will be direct seeded to wheat in 1997. Dan will have to make two passes in 1997 with the John Deere direct seeder. One pass to apply fertilizer and one to seed the wheat. The Barton openers will cut the sod into strips. Some problems may be encountered if the drill starts ripping out lumps of sod. The chopped up sod may dry out quicker than sod with only one pass of this seeder.

"Barton openers need to be experienced". There is a learning curve with any new technology. Modifications done in 1996 would probably have produced a better crop if implemented before seeding. The cleaning wheel is adjusted better now and more peas might have made it underground in all fields and the yields could have been higher.

Although 80 percent of the peas were dried at Cargill, they were harvested and sold unlike many farmers in the Peace Region who still have peas under snow during the winter of 1996-97. Dan will be out seeding next year's peas when these fellows are combining. So seeded peas earlier on sod that provided flotation during a wet harvest was definitely an advantage.

Dan intends to direct seed peas into sod (fescue, timothy or tall fescue) again. He thinks that if cold wet soil conditions exist in the spring he may let the field dry out and warm up more before direct seeding.

Overall it was a successful experiment and a learning experience.

Field Pea Production - Minimizing Risk and Increasing Yield Stability

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Farmers have indicated in the past few years that field pea yield has varied considerably from year to year and field to field. The range of field pea yield described by farmers has ranged from 10 to 100 bushels per acre in western Canada. Field pea will only be a beneficial crop in rotation if the risk of managing the crop is reduced and field pea yield stability becomes common. There are a number of management tools a farmer can utilize to manage risk and increase yield stability.

Soil versus seed inoculation with rhizobia

The objective of legume inoculation is to provide maximum numbers of viable, infective rhizobia in the developing rhizosphere so as to facilitate optimum nodulation of the root system. The literature demonstrates the importance of high rates of inoculation to achieve this objective. Seed inoculation or application of inoculant to the seed surface prior to planting is the traditional, most commonly used and user-friendly method. However there are some situations where application of the inoculant directly into the soil may be a more efficient means of inoculation. Brockwell et al. (4) have recently reviewed the literature in this regard, and concluded that "these methods (soil inoculation) are often better and never worse than the conventional seed inoculation for initiating nodulation and N_2 fixation".

The comparative effects of soil and seed inoculants is summarized for a number of studies in Table 1. Twelve of the 14 studies cited showed that soil applied inoculant resulted in an increase in one or more of nodule number, nodule weight, nitrogen fixation, plant biomass or grain yield. In the other two studies there was no response to inoculation. The significance of these findings is enhanced by the fact that the results are based mainly on field studies.

Only two studies reported on the use of liquid formulations for seed inoculation (Table 1). In one report peat seed-applied inoculant gave a significant response over liquid seed-applied inoculant. In the other report there was no difference between liquid and peat, and in general no significant response to inoculation.

In western Canada, seed inoculation is still the most important and common method of applying *Rhizobia* spp. to legumes, even though an alternative to conventional application has been available for 30 years. Direct application of peat powder inoculants to seed was the most

Table 1. Summary of studies on comparative effects of soil and seed applied inoclants.

Inoculant Type and Formulation	No. and Type of Studies	Crop	Response[1]	References
Soil/Granular, Seed/Peat	5 - field 1 - field	Soybean, Fababean, Field pea, Lupin Soybean	Soil > Seed Nil	1, 3, 8, 9, 12 13
Soil/Liquid, Seed/Peat	3 - field & greenhouse 1 - field	Soybean, Subterranean clover Soybean	Soil > Seed Nil	3, 7, 10[2] 2
Soil/Gran., Soil/Liq., Seed/Pt.	2 - field 2 - field	Soybean, Alfalfa Soybean, Chickpea	Soil/Gran > others Soil > Seed	6, 14 3
Seed/Liquid, Seed/Peat	1 - field 1 - field	Soybean Field pea, Lentil	Peat>Liquid Nil	5 11

[1] Increase in one or more of nodule number, nodule weight, nitrogen fixation, plant biomass or grain yield
[2] Soil > Seed for N_2 fixation and lateral nodulation, Seed > Soil for crown nodulation

common until an easier method of seed application was introduced with liquid inoculants. There are several situations in which seed application of rhizobia may be inefficient and include: 1) pre-emergence diseases make it necessary to use seed treatments of fungicides or insecticides, of which some may be toxic to rhizobia; 2) inoculation of legumes with large seed size and high seeding rates is a major task, restricting the speed of the seeding operation; 3) sometimes seeds are too fragile to be inoculated and over-handling can cause reduced germination and emergence; 4) the seed surface places a limit on the number of rhizobia which may be applied, a common problem when seed size is small or it is necessary to apply more of an introduced strain when there is naturally occurring rhizobia present; 5) the seed coats of some species may contain materials toxic to rhizobia.; 6) environmental stresses may contribute to increased rhizobia die-off on the seed and 7) seeding is delayed for 1-2 days because of inclement weather or equipment breakdowns and re-inoculation is necessary.

Seeding rates of field pea are commonly 150-180 kg ha^{-1} and the logistics of properly inoculating enough seed on the farm to seed a quarter section is a difficult task. Solid forms of inoculant introduced separately into the seedbed represents a satisfactory alternative to direct application of liquid or peat inoculant to the seed.

Starter nitrogen has been recommended for field pea production when soils are low in nitrogen. Also, farmers have increasingly utilized nitrogen when disappointing pea yields have prevailed on their farms to improve pea yield stability. Therefore, it is important to understand the role nitrogen plays in field pea production.

Consequently, studies were initiated in western Canada to compare inoculant formulation and starter N rates on the nodulation, growth, yield and nitrogen dynamics of field pea. Sites were situated at Minnedosa, Indian Head, Melfort, Stettler, Lacombe, Vegreville, Calahoo, Beaverlodge and Fort Vermilion covering the majority of the Parkland. All sites had never had field pea or lentil in the cropping history and were relatively low in nitrogen. Field pea was seeded on 8-12 inch row spacing depending on the seeding equipment available at each site with all but one site direct seeded. The inoculant formulations were seed applied (liquid and peat

powder) and soil applied (soil implant) at recommended rates of the manufacturers. An uninoculated check was also included to determine the presence of naturally occurring rhizobia. Four nitrogen rates were banded to the side and below the seed at rates of 20, 40 and 80 kg N ha^{-1} and a 0 N check and 11-51-0 was applied with the seed at a rate of 50 kg ha^{-1}. Four replicates, each with 16 treatments, in a randomized complete block design were seeded in a factorial arrangement. Data collected included total biomass at flatpod, nodule rating, seed yield, straw yield, total N from flatpod biomass, seed and straw, and N_2 fixation determined by the difference method. Canola was used as the reference crop.

The sites at Beaverlodge and Fort Vermilion showed the biggest variation in pea yield from the inoculant formulation, where soil applied inoculant produced pea yields that were higher than uninoculated and liquid treatments. Pea yield was higher from the seed applied liquid inoculant than from the uninoculated check at Beaverlodge but not at Fort Vermilion. The site at Indian Head also had pea yields that were higher from soil inoculation than from where pea seed was treated with liquid inoculant or were not inoculated at all. There were no significant differences in yield from the other sites between inoculant formulation or between inoculated and uninoculated treatments. Generally at these sites there was sufficient nodulation from naturally occurring rhizobia to support the plants need for nitrogen and consequently inoculation did not make a difference in productivity. At Minnedosa, Melfort, Lacombe and Vegreville it appeared the treatments nodulated in a way to express differences in yield between formulation treatments, however this expression wasn't apparent in growth. The data is limited at present to pea yield and until all the data is analysed, particularly the N dynamics, this information is inconclusive.

At all sites, adding starter N did not increase pea yield. Starter N decreased nodulation at most sites and pea yield declined at the higher N rate at some sites. Increasing the N rate at seeding decreased the nodulation on pea roots of the uninoculated treatment which suggests that applying nitrogen at seeding can inhibit the naturally occurring rhizobia.

Measurement of factors affecting the rhizobia/legume association in the field

Over the past two years we have observed a range in grain yield increase of 0 to 144% for field pea with granular soil inoculant as compared to peat seed inoculant. Further we have observed that, for example, seed inoculation with peat base inoculant gives very good response under some conditions, but not under others. The yield increase observed at a specific site varies with environmental factors including inoculant quality, levels of indigenous rhizobia, available soil nitrogen, soil moisture at seeding, soil type and general growing season conditions. It is , therefore, important to define these parameters when conducting field experiments with field pea so as to properly interpret results. It is also important to evaluate nodulation during the growing season.

One of the main reasons for including pulses in cropping systems is to take advantage of the N_2 fixing capability possessed by legumes. This development of this capability depends on the symbiotic interaction of two organisms—the legume plant and the rhizobia bacteria. The measurement of a few environmental factors and an assessment of nodulation development will provide insight into the level of activity of the N_2 fixing system and its impact on pulse crop

development. **A minimum requirement should be nodule assessment and when comparing inoculant formulation, an untreated check plot.**

The conclusion reached by Brockwell et al. (4) is certainly justifiable. The practical implications of the superior performance of soil inoculation is dependent on the comparative cost/production ratio of soil and seed applied inoculants. Over the past two years we have observed a range in grain yield increase of 0 to 140% for field pea with granular soil inoculant as compared to peat seed inoculant. Our results indicate that significant yield increases can be achieved with 5 kg/ha inoculant costing $8.36/ha more than conventional seed inoculation. The potential return on investment for adopting this management strategy is up to $525.00/ha. The actual return will vary depending on a number of environmental factors including levels of indigenous rhizobia, available soil nitrogen, soil moisture at seeding, soil type and general growing season conditions.

Other factors to manage risk and increase yield stability

In addition to inoculant formulation and reducing the amount of nitrogen applied to field pea, utilizing high vigor seed and ensuring high plant populations through seeding rate and direct seeding will increase the chance of success, minimize risk and increase field pea yield stability. Weed control through chemical and cultural methods will also minimize the risk of growing field pea. Providing an uncompetitive pea plant with a competitive advantage over weeds will improve the chances of yield stability.

Effect of field peas in rotation on soil microbial diversity

Crop rotation is another way to increase field pea yield stability as well as provide benefits to the following crop, in particular wheat. This benefit has been attributed to nitrogen left over from the previous pea crop, however, there are also other factors that seem to express this benefit. The role of soil micro-organisms has largely been ignored and may play a role in the benefit to the following crop. The effects of tillage and legume-based crop rotation on the diversity of bacteria under wheat were assessed in the field in a crop management study at Fort Vermilion. The tillage treatments were zero till (ZT) and conventional till (CT). Data for this study were collected in plots that had been preceded by field peas (FP), red clover green manure (GM), summer fallow (SF) or continuous wheat (CW). Soil was sampled prior to seeding and at flag-leaf stage of wheat growth in 1995 and 1996 growth seasons. At flag-leaf stage, diversity was assessed in rhizosphere and non-rhizosphere (bulk) samples. The Biolog method was used to evaluate diversity by examining patterns of utilization of 128 substrates by the bacterial community. From the data, Shannon's diversity index (H), which takes into account the number of different types of bacteria and their relative abundance in the soil, was calculated.

In 1995, the results showed no significant effects of tillage or crop rotation on bacterial diversity at planting time or in wheat rhizosphere at flag-leaf stage. In the bulk soil at flag-leaf stage, however, zero-till bulk soils had a more diverse bacterial community than conventional-till soils in every crop rotation both in 1995 and 1996. In 1995, field peas under conventional tillage increased diversity so much that zero-till had little further effect in these samples. Similar results were observed at planting time in 1996, when conventional-till plots preceded by legumes

(clover green manure or field peas) had higher bacterial diversity than conventional-till plots preceded by summer fallow or continuous wheat.

These results indicate that zero-tillage is superior to conventional tillage in enhancing microbial diversity, and that legumes in rotation, especially under conventional tillage, also enhance microbial diversity. This is important for long-term sustainability of agricultural systems because microorganisms mediate many functional processes that support such systems. These processes include the acquisition and recycling of nutrients required for plant growth, the maintenance of soil structure, the degradation of agro-chemicals and pollutants, and the control of plant and animal pests.

In summary, soil applied inoculant produced pea yields that were equal to or better than seed applied inoculant. Where significant differences did not occur, the uninoculated treatment produced pea yields that were equal to the inoculated treatments. Significant differences in nodulation occurred at some sites, yet pea yield differences were not expressed. Starter N does not appear beneficial to pea production. This is a preliminary look at the data collected from the inoculant formulation and nitrogen effect trials in western Canada so any conclusions drawn from here are premature. Data collected on flatpod biomass, harvest index, nitrogen dynamics and nitrogen fixation are required to complete the picture. The Biolog method may be a useful tool in understanding the effect of field pea on a following crop.

We gratefully acknowledge the financial support of the Alberta Pulse Growers Commission, Alberta Wheat Pool - Grande Prairie, Agriculture and Agri-Food Canada, Monsanto and CASEA.

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What to Do With Creeping Red Fescue If You Are a Zero Till Producer —Possible Methods For Making Life With Fescue Bearable—

Garry Ropchan

Research Coordinator
Central Peace Conservation Society, Spirit River

It is the normal practice for most producers who switch to zero till that after they become comfortable with this new style of management they begin to liquidate some of their equipment which is no longer being used. This is often able to help producers off-set the costs associated with buying a zero till drill.

So why do we want to grow fescue anyway? Especially if growing fescue is going to require that a zero till producer has to keep some tillage equipment around to rotate out of fescue. For some long term zero till producers from Manitoba, the benefits of zero till outweighed the benefits from having fescue in rotation and they made the decision that they would not be growing fescue any more. This may not be the case for all producers though, and so other options must be looked at. Peace Region producers continue to grow fescue due to its economic benefits. When grain prices have been low, fescue was one of the few money makers producers had along with canola.

Fescue also offers some attractive workload benefits.
1) fescue is usually underseeded with another crop, then grows for the next 3 to 4 years
2) only requirements are for fertility, weed control and harvesting
3) harvesting is done during August
4) soil conservation, not many producers will consider this, but grass sod is the ideal means of protecting soil

After fescue's useful lifespan

Fescue tends to become unproductive, usually after 4 years. What do we do with it now? The traditional practice is to engage in a little tillage, plow it, disc it several times, some cultivation, usually a year of fallow before it gets reseeded, counters the benefits we gained in soil protection from the sod. The other problems with this are the time and money it takes to remove the fescue.

Current expenses

Operation	Cost per acre
plowing	$20.00
discing	8.00
cultivating	6.50

Source: 1996 Alberta Agriculture Farm Operations Cost Guide

So in order to plow, disc twice and cultivate twice, we spend $49.00 per acre! Other options include plowing the sod, rolling it and then leaving it to grow back.

What else can we do?

Specifically what can zero till producers do with unproductive sod? If you converted to zero till then you most likely sold off tillage equipment or will do so if not needed in the new system.

How about rejuvenation?

If we can make the grass stand productive again then we need not worry about how to eliminate it. As fescue becomes unproductive when it reaches too high a plant population ("sod bound") if we can reduce the plant population we may be able to start the fescue's life cycle over again.

Looking at some Peace region trials conducted by CPCS

History

Thomi site. This was an old, unproductive fescue stand. It was sprayed in fall 1994 with ¾ liter Roundup. In 1995 sprayed with 1, 2 and 3 liters Roundup in spring. Oats were seeded. The plot unfortunately flooded and no data could be gathered.

In 1996 we left one replicate where 1, 2 and 3 l/ac Roundup had been sprayed and left it alone. As expected the fescue started to grow back! On August 9th we clipped 10 ½ by ½ meter samples, let them air dry and weighed the samples.

Results:

Treatment	Yield lb/ac
1 l/ac	441
2 l/ac	248
3 l/ac	360

There were no significant differences between the yields. These were reasonable first year yields, most producers would be happy to get this from a fescue crop seeded with normal practices. We will hopefully monitor the site again in 1997 to see if we can get the big fescue yields (600 to 800 lb/ac) that would normally occur in the second year.

Fescue and zero till

We have had two trials, the Thomi site and the Barlund site.

Thomi Site, 1995

Site is located 11 miles west of Woking. In the fall 1994, ¾ liter of Roundup was applied. In the spring of 1995, 1, 2 and 3 liters of Roundup applied in 5 gal/ac water using 110° nozzles, the fescue was about 6" high at this time.

We seeded untreated Derby oats at a rate of 105 lb/ac in a paired seed row using a Haybuster 8000 hoe drill. We applied 69-32-0-9 fertilizer blend deep banded 2" below and in middle of paired seed row. There were no problems with seeding operation. The 20" coulters on this drill cut through the sod so it does not get torn by the hoe shanks.

Observations

The 1 l/ac Roundup had poor control, 2 and 3 l/ac Roundup looked much better. The oat population was lower than desired indicating that higher seeding rates maybe warranted.

Treatment	Plant population/m2
1 l/ac	35.6a
2 l/ac	33.8a
3 l/ac	30.4a

Unsprayed area to side of plot had a population of 27.2 plants/m2. There were no significant differences between the plant populations. All oats showed signs of N deficiency (older leaves dying off to provide N for newer leaves) indicating that additional fertilizer maybe required for crop production.
We were unable to get results as snow fell, however they may not have provided any value as plot flooded during summer. Having said this, the unflooded knoll tops looked quiet good, tall and thick.

Thomi site, 1996

1 replicate was left for rejuvenation and 2 were used for 1996 plot. 2 l/ac Roundup was applied over the entire plot. Orb peas seeded, the peas emerged and plot was destroyed by flooding again!

Barlund site 1995

This plot is located 10 miles east of Wanham. The objective would be a comparison of fescue removal by tillage with fescue removal by herbicide. The tillage program was 1 plowing, 1 discing and 2 harrowings. The herbicide program was 2 l/ac Roundup with 1.5 l/ac ammonium sulfate in 5 gal/ac water using 110° nozzles on May 16 when fescue was 6 to 9" tall. Derby oats were seeded at a rate of 125 lb/ac 1.5" deep using a Haybuster 8000 drill equipped with paired seed rows. The fertility program consisted of 82-36-24-0 deep banded 2" below each paired seed row.

Observations

By June 27 you could see that the oats growing on the sod strips were shorter than the oats on the plowed strips, as well plant population looked lower on the sod strips.

Results

Treatment	Yield bu/ac	% Moisture	% Dockage	$/ac
Plowed Sod	124.7a	10.0a	0.5a	211.74
Sprayed Sod	79.8b	10.3a	0.5a	121.56

$/ac = gross income less tillage system costs and fertilizer costs averages followed by the same letter within groups not different at P=0.05

Conclusions

Both treatments still had high levels of fescue regrowth after swathing. This will not be a 1 year solution.

Barlund Site, 1996

May 23 we applied 2 l/ac Roundup with 2 l/ac ammonium sulfate, 5 gal/ac with 110° nozzles, we had good vigorous fescue growth at this time. The plowed strips were disced twice and harrowed twice on May 27. 115 lb/ac Derby oats were seeded 1" deep in a paired seed row using a Haybuster 8000 drill, seeded on May 28. 53 of N as anhydrous was deep banded 3" below the seed and 5.5-25-13-0 was placed with the seed.

Observations

On June 6 the plowed strips had to be harrowed due to crusting problems, this was **not required** on the sod sprayed strips. We applied Banvel and MCPA (120ml and 400 ml) incrop sprayed. Unlike 1995, no visible differences could be observed between treatments.

The crop was swathed on September 20th and then it snowed! We did cut some ½ meter wide chunks of swath that were allowed to dry and give some idea of the yield.

Treatment	Yield bu/ac	$/ac
Plowed Sod	78.0	138.25
Sprayed Sod	81.0	140.60

The plot will hopefully be harvested and weighed this spring given the opportunity.

It is our hope to continue with this research in 1997!

Tentative conclusions

1) herbicides can be used to bring unproductive fescue stands to a productive situation
2) it maybe possible to remove fescue without resorting to tillage with consecutive herbicide applications

Questions left to ponder

1) spring vs. fall application of herbicide
2) pre-harvest Roundup
3) air-sprayers, rolling prior to spraying.....

If you have any questions or comments please contact me at 864-3597.

Crop Variety vs Fertility Management

Crop Variety vs Fertility Management

Richard Lussier
Soils Management Specialist
AAFRD, Peace Region

Garry Ropchan
Program Coordinator
CPCS, Spirit River

Canola Production Survey

- differences between top 30% and bottom 30% of producers
- Five year average yields
  High producers: 30 bu/acre
  Low producers: 21 bu/acre
- tillage
- seed source and treatment
- herbicides

Canola Production Survey

- Differences in yield due to fertility soil testing: 67% of high producers
  25% of low producers

	lb/ac applied	
Nutrient	High	Low
N	82	46
P	35	21
K	9	7
S	13	8

Intensive Crop Management Systems Research Project

- four year study (FFTF Project #87-0163)
- crop variety, seeding rate, fertility, foliar fungicides and plant growth regulators
- Conclusions at the end of the study:
  "Of the variables studied, fertilizer applications had the greatest influence on crop yield."

Regional Variety Testing Program

- *"Fertilizer levels, weed controls, disease controls, etc., should be maintained at a level to encourage higher than average yields for that area."*

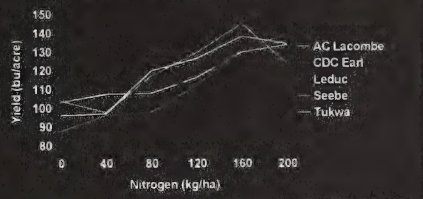
Canola Council Trials

- 1995 variety trial in Falher
- seeded on alfalfa plow-down/summerfallow
- 102 lbs of N applied (70 lbs in fall)
- Average for Peace region is only 46 lbs on fallow, 64 lbs on stubble

??????

- if variety trials could be conducted under "average" fertility conditions....
- do differences among varieties remain the same, and/or...
- do varietal rankings change as fertility levels change

Barley Response to Added Nitrogen (Millet, AB, 1996)

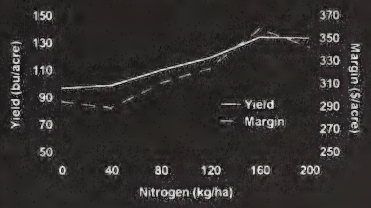


Agronomy Unit, 1996

Variety Ranking vs Fertility

	Ranking					
Variety	0	40	80	120	160	200
AC Lacombe	2	1	4	3	5	4
CDC Earl	5	5	5	5	4	1
Leduc	3	2	3	4	3	2
Seebe	1	3	2	1	1	5
Tukwa	4	4	1	2	2	3

Average Yield and Contribution Margins, (Millet, '96)



Peace region data

- CPCS conducted two field scale trials in the Spirit River area.
- Canola variety x fertility experiment 10 miles east of Wanham
- Hulless barley variety x fertility experiment at Blueberry Mountain

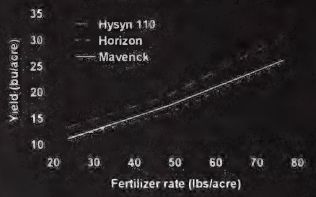
Canola variety x fertility

- three varieties used: Maverick, Horizon and Hysyn 110
- soil test recommendation:
  Excellent (35 bu/ac) 75-33-15-10
  Average (27 bu/ac) 72-31-15-10
- three fertilizer rates used: 24-11-05-03
  49-23-09-06
  77-35-15-09

Canola variety x fertility

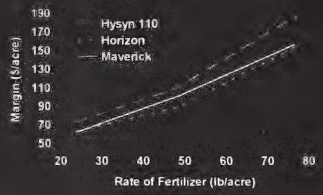
- seeded (no-till) June 5
- seeded at 10 bu/ac, 3/4" deep
- sprayed on July 5
- swathed Sept 5
- harvested October 12.

Canola variety x Fertility Wanham, 1996



CPCS, 1996

Contribution Margins. Wanham, 1996



Hulless barley variety x fertility

- CWB final payments (1995/1996):

Extra No. 1 CW	$3.61/bu
No.1 CW	$3.52/bu
Standard CW Hulless	$4.63/bu

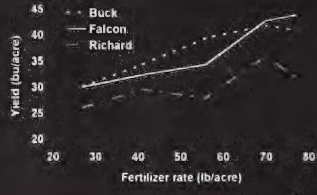
- three varieties: Falcon, CDC Richard, CDC Buck
- seeded June 10, harvested Nov 1

Hulless barley x fertility

- five fertilizer rates: 27-07-06-04
  41-10-09-06
  56-13-13-08
  70-17-16-10
  77-19-18-11
- Soil Test recommendation:

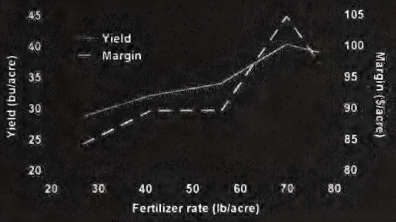
Excellent (77 bu/ac)	78-22-17-10
Average (59 bu/ac)	68-15-15-10

Hulless barley x fertility Blueberry Mtn., 1996



CPCS, 1996

Hulless barley profit margin



Conclusions

- difference among varieties varies from one fertilizer rate to another
- ranking of varietes change as move from one rate to another
- managing soil fertility according to soil test recommendations results in maximum returns

the end

Crop Rotations for Reduced Tillage

John Zylstra

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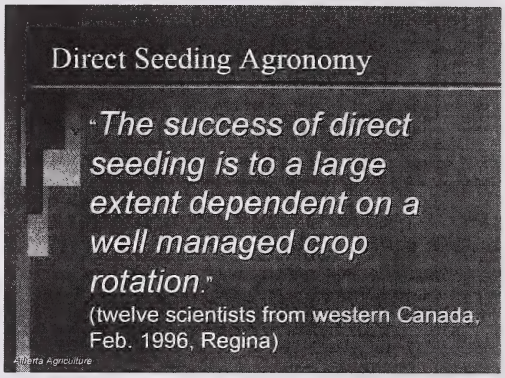
Alberta Agriculture, Food and Rural Development, Fairview

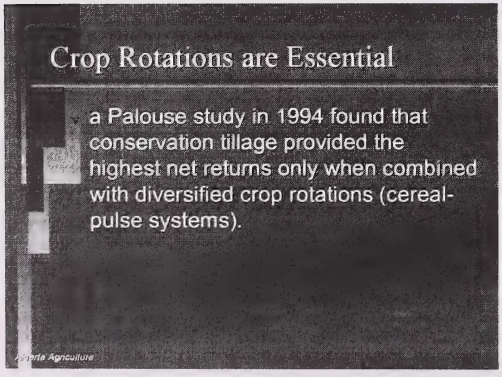
At a February 1996 conference organized by the Saskatchewan Soil Conservation Association in Regina, a group of scientists made a presentation on "Where are we going in Direct Seeding?" In this presentation, they stressed the importance of crop rotations.


Direct Seeding Agronomy
"The success of direct seeding is to a large extent dependent on a well managed crop rotation."
(twelve scientists from western Canada, Feb. 1996, Regina)
Alberta Agriculture

They said that the environmental (weather) conditions and crop rotations have a much larger effect on cereal disease levels than do tillage systems.

They said that cereals grown on canola stubble yield 5-15% higher than on cereal stubble, and cereals grown on pulse stubble yield 5-25% higher than on cereal stubble.

Not only does crop rotation help no-till crops, no-till also enhances rotation benefits. Peas under no-till or direct seeding often yield better, resulting in more nitrogen fixation, and more nitrogen available for future crops.


Crop Rotations are Essential
a Palouse study in 1994 found that conservation tillage provided the highest net returns only when combined with diversified crop rotations (cereal-pulse systems).
Alberta Agriculture

A Palouse study in 1994 found that conservation tillage provided the highest net returns only when combined with diversified crop rotations (cereal-pulse systems).

The benefit of rotations includes reducing diseases, adding nitrogen from pulse crops, and changing herbicides for better weed control.

The effect of rotations is also related to stubble height and stubble amounts. For example, in some situations increased stubble height promotes greater water use efficiency, resulting in higher yields. In some cases, soil moisture may be too high, resulting in delayed seeding. Another effect is that pea straw, being higher in protein (nitrogen content), will contribute more nitrogen to the succeeding crop.

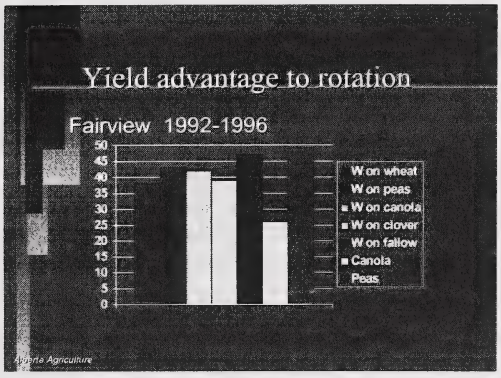
The benefit of pulse and legumes in rotation will depend greatly on the nitrogen-fixing done, which is also very dependent on the quality of the inoculum used or still present in the soil.

A Fairview crop rotation study found that wheat after peas or canola yielded 13% more than wheat seeded on wheat stubble.

The Fairview study consists of five three-year crop rotations. It was begun in 1992 at the Fairview Research Farm. The intent is to evaluate soil quality changes, if any, and the soil microbial changes particularly with peas. Also the relative advantages of the rotations are being evaluated.

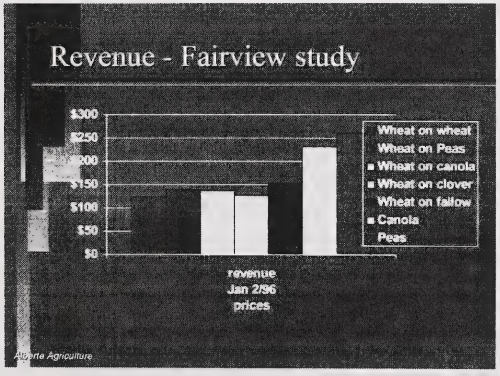
This site receives no fall tillage, and one tillage pass before seeding in the spring. Pre-seeding glyphosate is not normally used. Nitrogen-fertilizer has been broadcast before the single tillage pass. Most crop residue is still at the surface when seeding with a double disc press drill. Fertilizer levels are adjusted for the different plots by treatment, based on soil samples and previous crop. Nitrogen levels are reduced by about 20% for wheat following peas, compared to wheat after wheat or after canola.

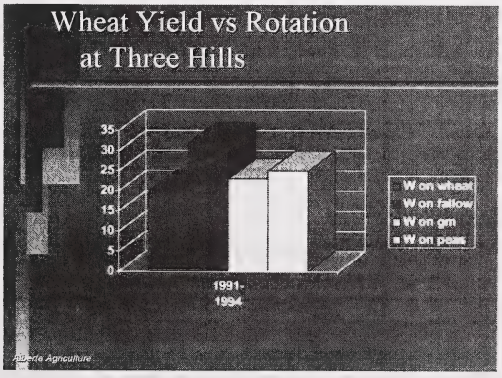
Plot sizes are 10 m x 20 m (33 x 66 ft) and are replicated three times.



Over four years, wheat seeded on pea or canola stubble has consistently outyielded wheat seeded on wheat stubble, averaging a 13% yield increase. The wheat on wheat stubble yields are a combination of wheat on wheat in all rotations, as each rotation has two years of wheat. If only the continuous wheat rotation is compared then the yield advantage for wheat on peas or canola is greater. In 1996, the continuous wheat plots have five years of continuous wheat. Although wheat yields on fallow and clover compare well with the others, they lose one crop every three years.

In 1995 and 1996, the wheat variety was AC Teal and the peas were Carneval. Before that Katepwa wheat and Express peas were used.





This Three Hills study done by Oosterhuis and Jensen includes eight different rotations. In 1994, the third year, yields of wheat on peas were higher than continuous wheat although not statistically significant.

A study at Scott, Saskatchewan in 1992-95 found that wheat seeded on canola and pea stubble outyielded continuous wheat yields by 12 bushels per acre. Net returns were about $40/acre higher for the crop rotation over continuous wheat.

According to plant pathologists, at least seven wheat diseases can be affected by crop rotation. These include common bunt, tanspot, mildew, septorias, fusarium, snow molds, common root rot, and take-all. A good crop rotation will reduce them all to some extent. The reduction of these diseases will result in better utilization of nutrients, better leaf and root growth and better yields.

Crop rotations help to control 11 barley diseases as well, including root rot, seedling blight, eyespot, powdery mildew, scald, leaf blotch, and take-all.

Crop rotations also help to control many canola diseases such as blackleg, sclerotinia, alternaria and others. Crop rotation is a better solution than burying stubble since even 10% of crop residue on the surface can infect a subsequent crop. One study by Turkington and Clayton found that canola stubble decays after two years under zero-till. After one and one-half years, zero-till had more canola stubble left on the surface, but after two years all tillage treatments had the same amount of canola residue.

A Saskatoon study by Stevenson and Van Kessel in 1994 at University of Saskatchewan found that wheat yield on small plots was 45% higher after peas than after wheat. On large (landscape) plots wheat after peas yielded 62% more than after wheat. The protein of wheat after peas was 15.4% vs 13.9% after wheat.

In this study, wheat and peas were seeded in 1993. Wheat was seeded in 1994.

On this Black soil, 80 kg/ha nitrogen was applied to the wheat in 1993. Only 45 kg/ha nitrogen was applied to the wheat in 1994. **(This may be the main reason for the large increase in wheat after peas.)** Glyphosate was applied pre-seeding; then they cultivated twice.

The landscape plots were 100 m x 100 m. The small plots were 4 m x 8 m.

Total nitrogen accumulation in the pea-wheat rotation increased by 46 kg/ha (in yield and protein levels).

Total soil nitrogen supplying power was 129 kg/ha greater.

Leaf diseases were 3.1 points (30%) lower on a 1-11 scale, for wheat after peas. This may also lead to greater root growth, regardless of actual root disease levels. This makes possible an increase in utilization of nitrogen and other nutrients left behind by pea roots and nodules.

Plant diseases were found to be spatially related up to distances of 15 to 25 m, so small plots may not be able to include the effects of diseases within different rotations, as well as larger plots.

This Saskatoon study also found that 9% of the yield increase after peas was due to extra nitrogen available; the rest of the yield advantage was due to other factors such as disease and weeds. More vigorous crop growth competition led to less grassy weed growth.

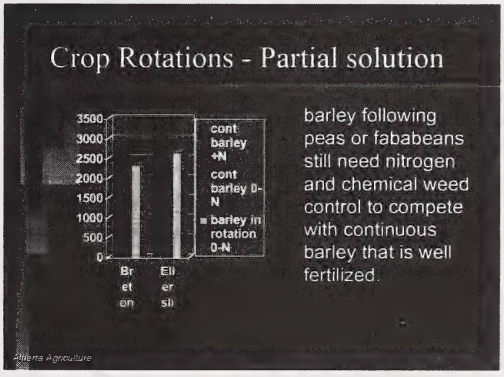
Wheat derived 2 kg/ha nitrogen from wheat residue vs 11 kg/ha from pea residue. In addition, three months after pea maturity, 35% of pea root nitrogen was available vs 12% of barley root nitrogen. So not only does pea straw and roots contain and provide more nitrogen, more of the nitrogen that it contains is available for future crops as well.

A 1990 study by Wright found that yields of barley and wheat increased by 20% following peas.

Barley following barley needed 100 kg/ha of nitrogen to produce the same yield as barley following peas (1990 study by Wright).

Crop rotations are a partial solution. A study was done by Izzaurralde and Haderlein from 1989 to 1994 at Ellerslie (Black soil) and Breton (Gray soil).

In this study, the barley in rotation was grown under low input conditions, without nitrogen added except from previous legume crop, and with no chemical weed control. This study shows that without fertilizer and herbicides, barley grown on pea stubble will not do as well as continuous barley that is well fertilized.



In summary, I want to stress that crop rotations reduce diseases; they increase average yields; they increase the advantage of direct seeding and are essential for direct seeding. In addition, peas are a crop that greatly add to rotation possibilities and strengths, adding yield, protein, soil fertility and disease control.

Global Positioning Systems/Precision Farming and Your Farm

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The technology and practice of precision farming has gained a lot of attention in the past several years. It promises an increase in net dollar return per acre when inputs can be adjusted to be most efficient over varying crop production potential of the landscape.

Many questions remain unanswered about how precision farming will actually work on the farm. However, one should know the steps which will be followed when the practice of precision farming is adopted.

There are five areas that must be addressed:

1. **Monitoring data from the field, including crop yield, soil fertility, soil moisture potential (low versus high areas of the field), and many others that have not been determined how to measure.**

The measurements possible are:

- crop yield **Precision Farming starts with** crop yield monitoring. Systems are available on most new combines and can be retrofitted to most current machines. When a yield monitor is combined with GPS, the yield and its position in the field can be stored in a computer file on-board the combine. This data will be used later in creating a visual map. After market yield monitors are available from Ag Leader, MicroTrak, and RDS.
- topography which might also indicate soil moisture
- soil nutrients
- soil salinity or pH
- soil organic matter
- field mapping and ground truthing

2. **Creating maps of the field data to visually present the information, particularly the variations in crop yield.**

At this point a major decision must be made. Do you want to create maps yourself or turn that over to a consultant (includes many agencies such as companies specializing in precision farming, fertilizer dealers, machinery dealers, farm supply outlets)? To create maps yourself, you must have an adequate computer to run the mapping software and *know how to use it.* As various companies develop their precision farming systems, the computer and mapping software often become part of the package.

3. **Analyzing field data to determine the relationship of crop yield to other characteristics of the soil and landscape.**

It is necessary to determine which of the measured features, or combination of them, actually affected the crop yield. The mapping software allows the crop yield data to be smoothed out so that the average yield or any yield above of below the average can be shown. The yield can be displayed in as many polygons as you wish. That directs you to particular parts of the field to determine what might have affected the yield at that location. Of particular interest are those things which you can control, or for which you can compensate. What was the nitrogen status there? Was the crop lodged or drowned out? Was it a weed problem? And so on.

4. **Determining how to change inputs of fertilizer, seed, pesticides, and other controls to maximize the net return from specific areas of the field and creating a computer map (file) which will control the field equipment.**

Presently, this is done manually. With the knowledge of agronomic needs of a crop and the status of the soil and potential growing environment in each polygon, you can create a prescription map of the inputs for each location. This task is tedious so a method needs to be developed to handle it. The software is only a short time away. Consultants are setting up services which take specific farm data, and create prescriptions. Typical CAD (computer aided drafting), and add-on modules in mapping software can be used for this purpose.

5. **Setting up field applicators so that a computer can provide information for specific inputs at the desired point in the field.**

Machinery is available today which can control the rate of agricultural inputs.

It can control:

- **Nutrients** (typically, two main fertilizer types plus 1 micro nutrient on existing farm equipment or any number of inputs with custom application).
- **Plant population** with seeding rate control (treated like any granular product).
- **Pesticides,** on/off, or rate changes. Pesticides which are needed only on patches of weeds mapped in a field, or are needed at various rates of concentration based on weed pressure can be controlled by similar equipment.
- **Plant variety changes** are possible for some crop types to reduce lodging or shorten time to maturity.

In fact, we can vary as many granular materials as the number of individual hoppers or tanks and meters that are present.

Liquids and anhydrous ammonia can be varied as well. In fact, variable meters for these products have been in use for several years, albeit manually controlled.

Conclusion: Install a yield monitor and GPS to create maps of your fields. Obtain a PC computer and use it to become proficient. Begin a study of your fields in relation to the yield maps to understand the reasons for crop variability. Use the GPS system for other tasks, such as driving around the country side or enjoying a boat on the lake (this increases your awareness of the advantages of positioning and is fun!).

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